## Contents

Program

<table>
<thead>
<tr>
<th>Session</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>Road Safety Plans and Strategies</td>
<td>13</td>
</tr>
<tr>
<td>Session 2</td>
<td>Preventive safety measures, audits, safety inspections</td>
<td>70</td>
</tr>
<tr>
<td>Session 3</td>
<td>Road Safety Plans and Strategies II</td>
<td>123</td>
</tr>
<tr>
<td>Session 4</td>
<td>Highlights of road safety in Europe – FERSI endorsed research</td>
<td>171</td>
</tr>
<tr>
<td>Session 5</td>
<td>Modelling</td>
<td>229</td>
</tr>
<tr>
<td>Session 6</td>
<td>Crash Recording Systems and Safety Auditing I</td>
<td>318</td>
</tr>
<tr>
<td>Session 7</td>
<td>Distraction, fatigue, alcohol and drugs related adverse effects on 381 driving</td>
<td>381</td>
</tr>
<tr>
<td>Session 8</td>
<td>Modelling II</td>
<td>460</td>
</tr>
<tr>
<td>Session 9</td>
<td>Crash Recording Systems and Safety Auditing II</td>
<td>531</td>
</tr>
<tr>
<td>Session 10</td>
<td>Vehicle innovations and ITS applications</td>
<td>587</td>
</tr>
<tr>
<td>Session 11</td>
<td>Road user education, driver licenses, special user groups: young, old, vulnerable</td>
<td>644</td>
</tr>
<tr>
<td>Session 12</td>
<td>Safety management techniques including speed management</td>
<td>696</td>
</tr>
<tr>
<td>Session 13</td>
<td>Interurban and rural safety, intersections, incident management</td>
<td>771</td>
</tr>
<tr>
<td>Session 14</td>
<td>Road user Education, driver licenses, special user groups: young, old, vulnerable</td>
<td>827</td>
</tr>
<tr>
<td>Session 15</td>
<td>Enforcement techniques, traffic laws and self enforcing design</td>
<td>889</td>
</tr>
<tr>
<td>Session 16</td>
<td>Traffic engineering innovations including road design and behavioural issues</td>
<td>949</td>
</tr>
<tr>
<td>Session 17</td>
<td>Fleet safety</td>
<td>996</td>
</tr>
<tr>
<td>Session 18</td>
<td>Health issues and raising awareness</td>
<td>1056</td>
</tr>
<tr>
<td>Posters</td>
<td></td>
<td>1117</td>
</tr>
</tbody>
</table>
Chairman of the 15th Road Safety on Four Continents conference:
H.E. Shaikh Hamdan bin Mubarak AlNahyan (Minister of Public Work, Chairman of NTA)

National organizing committee

- H.E. Dr. Nasser Saif Al Mansoori , Director General of NTA, Chairman
- Eng. Abdullah Salem Al Katheeri - National Transport Authority
- Mr. Nedal Faisal El Batayneh - National Transport Authority
- Bregadair General Ghaith Hasan Al Zaabi - Ministry of Interior
- Mr. Khaled Hashem - Department of Transport - Abu Dhabi
- Eng. Maitha Bin Adi - Road and Transport Authority - Dubai
- Mr. Abdullah Al Zari - Sharjah Transport
- Eng. Abdullah Saeed Al Shamsi - Abu Dhabi Municipality
- Bregadair General Hussain Mohammad Al Harthi - Saaed for traffic Systems
- Bregadair General Hasan Al Housani - Emirates Traffic Safety Society
- Dr. Gehad Youssif Asbaita - Emirates Driving Company
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Ása Forsman
strid Linder
Robert Thomson
Magnus Hjálmdahl
Jan Andersson
Björn Peters
Ho Seng Tim
Alberto José Silveira
George Giannopoulos
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Per Löken
Michael Lenné
Xiaoduan Sun
Joanna Zukowska
Terje Assum
Hans Joakim Vollpracht
Ahmad Farhan Mohd Sadullah
Tuenjai Fukuda
Atsushi Fukuda
Fridulf Sagberg
Laurent Carnis
Richard Cuerden
Juergen Ratj

Dieter Willersinn
Horst Schultze
Mohammed Taleb Obaidat
and Technology
Rikke Rysgaard
Kohinoor Kar Arizona
Azim Eskandarian
Karel Pospisil

VTI
UAE University Al-Ain
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Univ. of Hawaii (TRB)
FHWA (TRB)
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Luchemos por la Vida
Hellenic Institute of Transport
Hellenic Institute of Transport (FERSI)
SafeTraffic
MUARC
Univ. Of Louisiana
Gdansk Univ. Of Technology
TÖI
PIARC
MIROS
Nihon Univ.
Nihon Univ.
TÖI (ECTRI)
INRETS (ECTRI)
TRL (ECTRI)

DLR Institute of Transportation (ECTRI)
Frauenhofer-Institute for Information and Data Processing (ECTRI)
Bast (FERSI)
Jordan University of Science
GRSP
DOT
The George Washington University
CDV - Transport Research Centre

Sweden
UAE
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USA
USA
Canada
Finland
Hungary
Australia
Australia
South Africa
Sweden
Sweden
Sweden
Sweden
Singapore
Argentina
Greece
Norway
Australia
USA
Poland
Norway
Germany
Malaysia
Japan
Japan
Norway
France
United Kingdom
Germany
Germany
Jordan
Switzerland
USA
28 March

Registration 08.00-09.30

Opening Ceremony

09.30-11.00

Chairman:
H.E. Shaikh Hamdan bin Mubarak AlNahyan
(Minister of Public Work, Chairman of NTA)

Welcome addresses
H.H Shaikh Mohammad Bin Rashed Al Maktoum
(The vice president, Prime Minister, the ruler of Dubai)

RSAC Chairman - H.E. Shaikh Hamdan bin Mubarak AlNahyan
(Minister of Public Work, Chairman of NTA)

HE Mr Bruno Beijer, Ambassador of Sweden, United Arab Emirates

Mr Jonas Bjelkenstam, Director General, VTI

Coffee 11.00 - 11.30

Opening Session

11.30-13.00

Chairman:
H.E. Dr. Nasser Saif Al Mansouri (Director General of NTA)

Key note speech
Andrew Pearce, Chief Executive, Global Road Safety Partnership

Key note speech
“Research and Implementation Coming Together”
Richard Pain, TRB

Key note speech
Dr Syed Jaffar Hussain, WHO (to be confirmed)

Lunch 13.00-14.30
<table>
<thead>
<tr>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>14.30-16.00</strong></td>
<td><strong>14.30-16.00</strong></td>
</tr>
<tr>
<td><strong>Road Safety Plans and Strategies</strong></td>
<td><strong>Preventive safety measures, audits, safety inspections</strong></td>
</tr>
<tr>
<td>Chairman:</td>
<td>Chairman:</td>
</tr>
<tr>
<td>H.E. Eng. Hussain Al Harthi, Director of Abu Dhabi Traffic Department</td>
<td>Joanna Zukowska, Gdansk University of Technology, Poland</td>
</tr>
<tr>
<td>Sources of uncertainty in estimated benefits of road safety programmes</td>
<td>Collection of road and roadside data to help address road safety risk</td>
</tr>
<tr>
<td>Rune Elvik, Institute of Transport Economics, Norway</td>
<td>Blair Turner, ARRB Group, Australia</td>
</tr>
<tr>
<td>Systemic Traffic Risk Assessment: A Useful Tool That Could Be Put Into Practice In Argentina</td>
<td>Outcomes from a large scale road safety audit of the existing Dubai road network</td>
</tr>
<tr>
<td>Gustavo Zini, School of Engineering - University of Buenos Aires, Argentina</td>
<td>John Hughes, ARRB Group, Australia</td>
</tr>
<tr>
<td>Are Speed Cameras Effective in Reducing Road Crashes in the Emirate of Abu Dhabi?</td>
<td>Recommendations for the adjustment of existing rural roads towards self explaining roads</td>
</tr>
<tr>
<td>Dr. Arif Mehmood, Department of Transport, Abu Dhabi, United Arab Emirates</td>
<td>Thomas Richter, Technische Universität Berlin, department road planning and operation, Germany</td>
</tr>
<tr>
<td>Developing a Road Safety Strategy for the Emirate of Abu Dhabi</td>
<td>Narratives and Accidents</td>
</tr>
<tr>
<td>Mr Jamie Castle, TRL, UK</td>
<td>Beate Elvebakk, Institute of Transport Economics, Norway</td>
</tr>
<tr>
<td>Recent road safety strategies in Hungary</td>
<td>Measurement of Unsafe behaviour of road users</td>
</tr>
<tr>
<td>Prof.Dr.Péter Holló, Tamás Berta, KTI Institute for Transport Sciences Non-profit Ltd., Hungary</td>
<td>Pr. H. Boudrifa, Laboratory of Prevention and Ergonomics; The university of Algiers, Algeria</td>
</tr>
</tbody>
</table>

Coffee 16.00-16.30
<table>
<thead>
<tr>
<th>Session 3</th>
<th>Session 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>16.30-18.00</strong>&lt;br&gt;Road Safety Plans and Strategies II</td>
<td><strong>16.30-18.00</strong>&lt;br&gt;Highlights of road safety in Europe - FERSI endorsed research</td>
</tr>
<tr>
<td><strong>Chairman:</strong>&lt;br&gt;Andrew Pearce, GRSP</td>
<td><strong>Chairman:</strong>&lt;br&gt;Evangelos Bekiaris, Hellenic Institute of Transport, Greece</td>
</tr>
<tr>
<td>Australia’s new approach to road safety: How is the Safe System approach being implemented?&lt;br&gt;Blair Turner, ARRB Group, Australia</td>
<td>Driving Under the Influence of Drugs, Alcohol and Medicines: DRUID Project&lt;br&gt;Horst Schulze, Bundesanstalt für Straßenwesen (BASt), Germany</td>
</tr>
<tr>
<td>Organising For Road Safety In Bangladesh: Some Challenges And Opportunities&lt;br&gt;Dr. Md. Mazharul Hoque, Department of Civil Engineering, BUET, Bangladesh</td>
<td>Integrated system for safe transportation of children to school, Safeway2school&lt;br&gt;Anna Anund, VTI, Sweden</td>
</tr>
<tr>
<td>3 Step Generic Procedure To Assess Road Safety: A Case Study of Egypt&lt;br&gt;Dr. Khaled Abbas, Roads &amp; Transport Authority, Dubai, United Arab Emirates</td>
<td>Naturalistic rider studies for the analysis of riders’ behaviour and safety (2BESAFE)&lt;br&gt;Stéphane Espié, INRETS, France</td>
</tr>
<tr>
<td>Effective Road-Safety policy making in lower-income countries: Ten principles from social systems thinking&lt;br&gt;Alfredo del Valle, Universidad Alberto Hurtado, Santiago, Chile</td>
<td>PRoMoting real Life Observations for Gaining Understanding of road user behaviour in Europe (PROLOGUE)&lt;br&gt;Ingrid van Schagen, SWOV Institute for Road Safety Research, The Netherlands</td>
</tr>
<tr>
<td>Road Safety Strategies of Abu Dhabi Municipality&lt;br&gt;Rauf Iqbal, Municipality of Abu Dhabi City, United Arab Emirates</td>
<td>SAFERIDER: Can Based Architecture on 2-Wheelers Domain&lt;br&gt;Roberto Montanari, University of Modena &amp; Reggio Emilia, Italy</td>
</tr>
<tr>
<td>Integrated Safety &amp; Security for transportation hubs – SAVE ME&lt;br&gt;Maria Panou, Hellenic Institute of Transport, Greece</td>
<td></td>
</tr>
<tr>
<td>Session 5</td>
<td>Session 6</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>09.30-11.00</strong></td>
<td><strong>09.30-11.00</strong></td>
</tr>
<tr>
<td><strong>Modelling</strong></td>
<td><strong>Crash Recording Systems and Safety Auditing I</strong></td>
</tr>
<tr>
<td><strong>Chairman:</strong></td>
<td><strong>Chairman:</strong></td>
</tr>
<tr>
<td>Geert Wets, IMOB - Hasselt University, Belgium</td>
<td>Wahid Ali AL-Kharuzi, Oman</td>
</tr>
<tr>
<td><strong>Modelling the Safety of Intersections</strong></td>
<td><strong>Evaluation of Road Traffic Accidents in Germany - Need of Data and Analysis</strong></td>
</tr>
<tr>
<td>Dr Majid Sarvi, Department of Civil Engineering, Monash University, Australia</td>
<td>Sabine Degener, Unfallforschung der Versicherer, Germany</td>
</tr>
<tr>
<td><strong>GRSI-Beijing Project of Improving VRU’s Safety at Junctions</strong></td>
<td><strong>Road Crash and Victim Information System</strong></td>
</tr>
<tr>
<td>Yanyan Chen</td>
<td>Panhavuth SEM, Handicap International Belgium, Cambodia</td>
</tr>
<tr>
<td>Beijing University of Technology China</td>
<td><strong>A Data Quality Case Study for Turkish Highway Accident Data Sets</strong></td>
</tr>
<tr>
<td><strong>Measuring The Risk of Road Crashes</strong></td>
<td>Omur Kaygisiz, General Directorate of security, Traffic Research Center, Turkey</td>
</tr>
<tr>
<td>Aline Chouinard, Transport Canada, Canada</td>
<td><strong>Assessment of Crash Database System of United Arab Emirates</strong></td>
</tr>
<tr>
<td><strong>Bringing Structure into Road Safety Evaluation: A Hierarchy of Indicators</strong></td>
<td>Md. Bayzid Khan, United Arab Emirates University, United Arab Emirates</td>
</tr>
<tr>
<td>Tom Brijs, IMOB - Hasselt, University, Belgium</td>
<td><strong>Characteristics of Injury Crashes in Dubai UAE</strong></td>
</tr>
<tr>
<td><strong>Road Safety Evaluation and Target Setting using Data Envelopment Analysis</strong></td>
<td>Mostapha Al-Dah, ESRI, Loughborough University, UK</td>
</tr>
<tr>
<td><strong>Evaluation of Methods for Pedestrian Safety Improvement on Left-Turning Vehicles Movement</strong></td>
<td></td>
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<tr>
<td>Hassan Zoghi</td>
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<tr>
<td>Islamic Azad University, Karaj Branch, Tehran Iran</td>
<td></td>
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<tr>
<td><strong>Only published in proceedings:</strong></td>
<td><strong>Multilevel Data in Traffic Safety: a 5xST-level Hierarchy</strong></td>
</tr>
<tr>
<td></td>
<td>Helalai Huang, University of Central Florida, USA</td>
</tr>
</tbody>
</table>

**Coffee 11.00-11.30**
### Session 8

**11.30-13.00**
**Modelling II**

**Chairman:**
Tom Brijs, IMOB - Hasselt University, Belgium

**A computational model to assess the impact of a set of policy measures on traffic safety at the regional level**
Geert Wets, IMOB - Hasselt University, Belgium

**A More Precise Approach for Road Safety Scoring**
Ahmet Yildiz, Dep. for Spatial Development, Infrastructure and Environment Planning, Vienna, Austria

**Computer-aided Road Safety Inspections**
Ahmet Yildiz, Dep. for Spatial Development, Infrastructure and Environment Planning, Vienna, Austria

**Development of a new Driver behaviour model through a novel object detection technique**
Dr Majid Sarvi, Civil Engineering, Monash University, Australia

**Automated Road Safety Analysis Using Computer Vision Techniques**
Tarek Sayed, University of British Columbia, Canada

*Only published in proceedings: Macroscopic Safety Investigation at the Traffic Analysis Zone Level*
Mohamed Abdel-Aty, Department of Civil, Environmental and Construction Engineering, University of Central Florida, USA

### Session 9

**11.30-13.00**
**Crash Recording Systems and Safety Auditing II**

**Chairman:**
Mahmoud Fekri, Health Dept., Abu Dhabi, United Arab Emirates

**Elderly Driver Traffic Citations in Hawaii, 1996-2006**
Karl Kim, University of Hawaii, USA

**Influence of Accident Cause on Ranking Hazardous Road Sections**
Mahmoud Saffarzadeh, Tarbiat Modares University, Tehran, Iran

**Identification of Accident Black Spots on Rural Highways in India: Case Study of Maharashtra State**
Dattatraya Tukaram Thube, Public Works Department, Government of Maharashtra, India

**Analysis of Risk Factors for Rear-end Collisions by Using Drive-recorder Data**
Shigeru Tominaga, College of Science and Technology, Nihon University, Japan

**In-Depth Investigation of Severe and Fatal Roadway Crashes in the Emirate of Abu Dhabi-UAE**
Jens Thomsen Health Authority, Abu Dhabi, United Arab Emirates

### Session 10

**11.30-13.00**
**Vehicle innovations and ITS applications**

**Chairman:**
Yasser Hawas, UAE University Al Ain, UAE

**The Effectiveness of Antilock Brakes Systems on Motorcycles in Reducing Real Life Crashes and Injuries**
Matteo Rizzi, Vectura Consulting, Sweden

**Motorcyclist Spinal Injuries in Road Crashes: Literature Review**
Zarir Hafiz Zulkipli, Malaysian Institute of Road Safety Research (MIROS), Malaysia

**Automated Truck Platoons on Motorways – A Contribution to the Safety on Roads**
Eckart Hauck, RWTH Aachen University, ZLW/IMA, Germany

**Mobile Traffic Safety Integration with off Board Navigation – (MOTION). Evaluation of acceptance and traffic safety with a Speed Alert function**
Magnus Hjälmdahl, VTI, Sweden

**Evaluation on Impact of Adaptive Cruise Control Installation on Reduction of Collision Using Micro Traffic Simulation**
Atsushi Fukuda, Nihon University, Japan

Lunch 13.00-14.00
<table>
<thead>
<tr>
<th>Session 11</th>
<th>Session 12</th>
<th>Session 13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>14.00-15.30</strong>&lt;br&gt;<strong>Road user education, driver licenses, special user groups: young, old, vulnerable</strong>&lt;br&gt;Chairman:&lt;br&gt;Gehad Esbaita,&lt;br&gt;EDC, United Arab Emirates&lt;br&gt;Ambient intelligence in driving simulation for training young drivers&lt;br&gt;Evangelos Bekiaris, Hellenic Institute of Transport, Greece&lt;br&gt;Improving driver education with multimedia applications&lt;br&gt;Tibor Petzoldt, Chemnitz University of Technology, Germany&lt;br&gt;The New Road Safety Programme for Comprehensive School of Lithuania: theoretic and didactic aspects&lt;br&gt;Rytis Vilkonis, Faculty of Education, Siauliai University, Lithuania&lt;br&gt;Experiences of Helmet Wearing Promotion and Enforcement in Cambodia&lt;br&gt;Chandy MEAS, Handicap International Belgium, Cambodia</td>
<td><strong>14.00-15.30</strong>&lt;br&gt;<strong>Safety management techniques including speed management</strong>&lt;br&gt;Chairman:&lt;br&gt;Laurent Carnis,&lt;br&gt;INRETS/DEST, France&lt;br&gt;Speed and Safety: Evidence from Highways in China&lt;br&gt;Xiaoduan Sun, University of Louisiana, USA&lt;br&gt;Differentiated rural speed limits - can this be done safe?&lt;br&gt;Jesper Mertner, COWI A/S, Denmark&lt;br&gt;A Practical Traffic Safety Activity by Utilizing Identified Hazardous Map Development to Raise Road Safety Awareness in Thai Community&lt;br&gt;Tuenjai Fukuda, Research Institute of Science and Technology, Nihon University, Japan&lt;br&gt;Implementing Traffic Safety Community-Based Activity for Development of Traffic Safety Culture in Vietnam&lt;br&gt;Tuenjai FUKUDA, Research Institute of Science and Technology, Nihon University, Japan&lt;br&gt;Quantitative Assessment of Used Tires Impact on Road Safety in Developing Countries&lt;br&gt;Mr. Godfrey Lamptey, P.E. Corzo Castella Carballo Thompson Salman (C3TS), USA</td>
<td><strong>14.00-15.30</strong>&lt;br&gt;<strong>Interurban and rural safety, intersections, incident management</strong>&lt;br&gt;Chairman:&lt;br&gt;Ho Seng Tim,&lt;br&gt;LTA, Singapore&lt;br&gt;Fatality Analysis of Intersection Accidents in Bangladesh&lt;br&gt;Sabreena Anowar, University of Calgary, Canada&lt;br&gt;Severity Analysis of Heavy Vehicle Accidents of Bangladesh&lt;br&gt;Shamsunnahar Yasmin, University of Calgary, Canada&lt;br&gt;Investigating Driver’s Behaviour Change by Signal Countdown Devices at Intersections in Beijing&lt;br&gt;Yulong He, Beijing University of Technology, China&lt;br&gt;Accident characteristics by Road Types on Singapore Roads&lt;br&gt;Koh Puay Ping, Land Transport Authority LTA, Singapore&lt;br&gt;Stopping Propensity at Red Lights in Saudi Arabia&lt;br&gt;Salaheddine Bendak, Dallah Human Skills Development Company, Saudi Arabia</td>
</tr>
</tbody>
</table>

*Coffee 15.30-16.00*
### Session 14

**16.00-17.30**  
**Road user education, driver licenses, special user groups: young, old, vulnerable**

**Chairman:**  
Dr Bassam Ahmad Anani, Abu Dhabi, DOT, UAE

- Vulnerable Road User Safety across several international regions  
  Brian Fildes, Monash University Accident Research Centre, Europe, Australia/Italy

- Dubai Pedestrian Safety & Mobility Action Plan  
  Saad Al Asady, Roads & Transport Authority, Dubai, United Arab Emirates

- Comparative Cross-Cultural Analyses on Road Safety among Vulnerable Road Users  
  Ernest Agyemang, NTNU, Norway/University of Ghana, Ghana

- Bicycle helmets, risk compensation and cyclist types  
  Aslak Fyhri, Institute of Transport Economics, Norway

- Criteria for age based design of Active Vehicle Safety Systems  
  Eckart Hauk, Aachen University, Germany

### Session 15

**16.00-17.30**  
**Enforcement techniques, traffic laws and self enforcing designs**

**Chairman:**  
Terje Assum, Institute of Transport Economics, Norway

- Effectiveness of a System of Automatic Speed Control on Poland’s National Roads  
  Mariusz Kiec, Cracow University of Technology, Poland

- Knowing your speed can save your life  
  Koh Puay Ping  
  Land Transport Authority  
  Singapore

- Speed Enforcement in France: A Decade of Changes (2000-2009)  
  CARNIS Laurent, INRETS/DEST, France

- An Assessment of Road Safety and Accident Policy Transitions and Pathways in Uganda: Milestones and Priorities for Immediate Action  
  Paul Isolo Mukwaya, Department of Geography Makerere University, Uganda

- Assessment of the Traffic Monitoring Technologies of Relevance to Traffic Safety in UAE  
  Faisal Ahmed, (RTTSRC) UAE University, Al Ain, United Arab Emirates

### Session 16

**16.00-17.30**  
**Traffic engineering innovations including road design and behavioural issues**

**Chairman:**  
Peter Hollo, KTI, Hungary

- Effects of traffic and geometric features on hazardous maneuvers  
  Francesco Bella, Department of Sciences of Civil Engineering/Roma TRE University, Italy

- Different Designs of Cycle Tracks and Lanes - The Effect on Objective and Subjective Safety  
  Michael Sørensen, Institute of Transport Economics, Norway

- A New Methodology for Implementing Road Design Guidelines in Thailand  
  Andreas Vesper, Bauhaus-University Weimar, Department of Transport Planning and Traffic Engineering, Germany

- Drivers’ risk perception assessment. The case of highways with poor geometric characteristics, in heavy traffic conditions  
  Prof. Nikolaos Eliou, University of Thessaly, Greece

- The potential to Implement a Superstreet as an Unconventional Arterial Intersection Design in South Korea  
  Young-Rok Kim, Highway Research Division, Infrastructure Research Department, Korea Institute of Construction Technology, Korea

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**Conference Dinner**
### Session 17

**09.30-11.00**

**Fleet safety**

**Chairman:**
Tuenjai Fukuda,
Nihon University, Japan

**Stimulating Traffic Safety of (Delivery) Vans by Enhancing the Company’s Safety Culture**
Annick Starren, TNO, The Netherlands

**Development of Road Safety Network in Cambodia**
Chandy MEAS, Handicap International Belgium, Cambodia

**Safety culture in bus transport compared to rail and air transport**
Torkel Bjørnskau, Institute of Transport Economics, Norway

**An innovative approach to addressing heavy commercial vehicle safety**
Adam Ritzinger, ARRB Group Ltd, Australia

**Examples of approachable fatigue management practices in transport companies in the Netherlands**
Annick Starren
TNO
The Netherlands

### Session 18

**09.30-11.00**

**Health issues and raising awareness**

**Chairman:**
H.E. Abdulla Al Zeri. Sharjah Transport, United Arab Emirates

**Status of Traffic Safety in the UAE**
Mohammad Nurul Hassan
RTTSRC, Research Affairs, UAE University
United Arab Emirates

**Research Directions for Guidelines in Road Safety Engineering**
Peter Croft, ARRB Group, Australia

**Lives of road accident victims and their families**
Joanna Zukowska, Gdansk University of Technology, Poland

**Road Safety in Tanzania – A Questionnaire Study**
Katja Kircher, VTI, Sweden

**Assessment of Road User Behavioral Aspects of Relevance to Traffic Safety in UAE**
Nada Al Naser, Roadway Transportation and Traffic Safety Research Center (RTTSRC)/United Arab Emirates University (UAE University), United Arab Emirates

### Session 19

**09.30-11.00**

**Road Safety Activities in the MENA Region (MENARSP sponsored)**

**Chairman:**
Dr Nabil Safwat, ESCWA, Lebanon

**Development and Partnership achievements by MENARSP**
Samar Abouraad, GRSP, Lebanon

**Results of the UN Road safety Targets Workshop**
Dr Nabil Safwat, ESCWA, Lebanon

**Road Safety Strategies developed in some MENA countries**
Peter Elsenaar, GRSP, The Netherlands

**Examples of some Partnership projects by Shell**
Hendrik Moorrees, Shell, Oman

Coffee 11.00-11.30
# 30 March

## Closing Session 11.30-13.00

<table>
<thead>
<tr>
<th>Summary of Global Road Safety</th>
<th>Closing Address</th>
<th>Closing Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Elsner, GRSP, Switzerland</td>
<td>NTA</td>
<td>Kent Gustafson, Chairman of RS4C organizing committee, VTI</td>
</tr>
</tbody>
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| Lunch 13.00-14.00 |

## Poster Session

### May be subject to change into oral presentations

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Z.A. Ahmad Noor Syukri Malaysian Institute of Road Safety Research Malaysia</td>
<td>Deniz Atalar Ergonomics and Safety Research Institute, Loughborough University UK</td>
<td>Hamid Reza Behnood Techno-Economic Road Safety Research Center, Ferdowsi University of Mashhad Iran</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A Safety Audit Approach in Ranking Urban Black Spots Using Analytical Hierarchy Process (AHP), (Case Study: Region 20 of Tehran)</th>
<th>Setting Appropriate Posted Speed Limit for the Emirate of Abu Dhabi</th>
<th>A Simulation-Based Traffic Safety Evaluation of Signalized and Un-Signalized Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mohsen Fallah Zavareh Traffic and Transportation Deputy, Municipality of Tehran Iran</td>
<td>Abdullah Zineddin Abu Dhabi Department of Transport United Arab Emirates</td>
<td>Tom Brijs Transportation Research Institute (IMOB) Hasselt University Belgium</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting up an indicator system for monitoring road safety using the road safety target hierarchy</th>
<th>Vehicles’ Type and Engine Power as Factors Affecting Drivers’ Risk Perception of the Geometric Characteristics of Road Network</th>
<th>The Malaysian Value of Reducing Fatal and Non Fatal Injuries Due to Road Accidents: A Willingness to Pay Study Using Conjoint Analysis Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gert Wets IMOB - Hasselt University Belgium</td>
<td>Prof. Nikolaos Eliou University of Thessaly Greece</td>
<td>Prof Hj Mohd, Faudzi Mohd Yusof Malaysian Institute of Road Safety Research Malaysia</td>
</tr>
</tbody>
</table>
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Partners, level 2

Decision Makers TV

Sharjah Transport

Supporting Organisations
Contents session 1 Road Safety Plans and Strategies

Sources of Uncertainty in Estimated Benefits of Road Safety Programmes
Rune Elvik, Institute of Transport Economics, Norway

Systemic Traffic Risk Assessment: A Useful Tool That Could Be Put Into Practice In Argentina
Gustavo Zini, School of Engineering – University of Buenos Aires, Argentina

Are Speed Cameras Effective in Reducing Road Crashes in the Emirate of Abu Dhabi?
Dr. Arif Mehmood, Department of Transport, Abu Dhabi, United Arab Emirates

Development a Road Safety Strategy for the Emirate of Abu Dhabi
Mr Jamie Castle, TRL, UK

Recent Road Safety Strategies in Hungary
Prof. Dr. Péter Holló and Tamás Berta, TI Institute for Transport Hungary, Sciences Non-profit Ltd., Hungary
ABSTRACT
National road safety programmes have been developed in many motorised countries. Some of these programmes contain estimates of the safety benefits that were expected to be realised if the programmes were fully implemented. When these estimates are compared to actual outcomes, it is not uncommon to find large differences. This paper shows that differences between the predicted and actual results of road safety programmes should not come as a surprise, but is the result of the large, but generally unrecognised, uncertainty inherent in estimates of the effects of such programmes. More specifically, the following sources of uncertainty can be identified:

1. Random variation in the recorded number of accidents or injuries in the target group of a road safety measure;
2. Incomplete or inaccurate reporting of accidents or injuries in official accident statistics;
3. Uncertainty about the definition of the target group of accidents or injuries influenced by a road safety measure;
4. Random variation in the effects of a road safety measure on accidents or injuries;
5. Unknown sources of systematic variation in the effects of a road safety measure on accidents or injuries;
6. Unknown duration or stability over time of the effects of a road safety measure;
7. Uncertainty with respect to if and how the first order effects of a road safety measure are modified when it is combined with other road safety measures;
8. Uncertainty with respect to assumptions made about the effects of exogenous factors influencing road safety;
9. Uncertainty about the degree to which planned road safety measures will actually be implemented;
10. Uncertain monetary valuation of the benefits of road safety measures.

The possibility of describing these sources of uncertainty numerically, and of estimating their joint contribution, is discussed. It is concluded that at the current state of knowledge, it is not possible to meaningfully estimate the total uncertainty inherent in road safety programmes.

1 INTRODUCTION
Quantified targets for improving road safety and programmes designed to realise these targets have been adopted by many motorised countries in recent years. These programmes do not always produce the expected results. On the contrary, it is commonly found that the actual number of people killed or injured in road accidents exceeds the numbers that were predicted according to the road safety programme.

Road safety is influenced by very many factors and no road safety programme can hope to influence all of them. Road safety is therefore only to some extent controllable by means of
government programmes. Besides, the effects of a programme on road safety are highly uncertain – more so than is generally recognised. Indeed, one could argue that if the uncertainty of the effects of a road safety programme was fully known and recognised, it should not come as a surprise that actual road safety outcomes differ from those envisaged by a road safety programme. This paper is a first attempt to study the following questions:

1. What are the principal sources of uncertainty in the estimated benefits of national road safety programmes?
2. Is it possible to quantify all sources of uncertainty?
3. Is it possible to estimate the joint contribution of all sources of uncertainty, i.e. the total uncertainty associated with estimates of the benefits of a road safety programme?

The term “benefits” refers to the monetary benefits of a road safety programme in terms of reduced costs of accidents and other favourable impacts. Very often, however, the principal focus of interest is on effects stated in terms of changes in the number of people killed or injured. These impacts are the principal focus of interest in this paper as well. The reason for including the monetary valuation of impacts in the analysis will be explained later.

2 EXAMPLES OF ERRONEOUS ESTIMATES OF EFFECTS OF ROAD SAFETY PROGRAMMES

It is easy to give examples of road safety programmes that have not resulted in the safety benefits they were expected to produce. Figure 1 gives one example. It shows road accident fatalities in Denmark from 1989 to 2000 compared to the targeted development according to a road safety programme proposed in 1988 (Færdselssikkerhedskommissionen 1988).

![Figure 1: Planned and actual number of fatalities according to Danish road safety programme 1988-2000](image)

During the first years, outcomes were close the road safety programme, but then progress slowed down. At the end of the period, the actual number of road accident fatalities clearly
exceeded the number expected to occur according to the road safety programme. Similar examples can be given for Finland (Trafiksäkerhetsdelegationen 1982) and Sweden (Vägverket 1999). For Norway, on the other hand, the number of fatalities has developed more favourably than predicted in the National Transport Plan for the 2002-2011 term (Samferdselsdepartementet 2000). Thus, although too optimistic predictions appear to be more common than too pessimistic, examples of both these errors can be found. Since erroneous predictions of the impacts of road safety policy are not intentional, these errors must be attributable to sources of uncertainty in estimates of programme impacts that were either unrecognised or erroneously estimated when the programme was prepared.

3 A TAXONOMY OF SOURCES OF UNCERTAINTY

There are several sources of uncertainty in the estimated benefits of national road safety programmes. This paper will discuss the following sources of uncertainty.

1. Random variation in the recorded number of accidents or injuries in the target group of a road safety measure;
2. Incomplete or inaccurate reporting of accidents or injuries in official accident statistics;
3. Uncertainty about the definition of the target group of accidents or injuries influenced by a road safety measure;
4. Random variation in the effects of a road safety measure on accidents or injuries;
5. Unknown sources of systematic variation in the effects of a road safety measure on accidents or injuries;
6. Unknown duration or stability over time of the effects of a road safety measure;
7. Uncertainty with respect to if and how the first order effects of a road safety measure are modified when it is combined with other road safety measures;
8. Uncertainty with respect to assumptions made about the effects of exogenous factors influencing road safety;
9. Uncertainty about the degree to which planned road safety measures will actually be implemented;
10. Uncertain monetary valuation of the benefits of road safety measures.

Each of these sources of uncertainty will be briefly described.

3.1 Random variation in the target number of accidents or injuries influenced by each road safety measure

A road safety programme will normally consist of a number of road safety measures. Each of these measures is intended to influence a certain target group of accidents or injuries. As an example, converting junctions to roundabouts will influence the number of accidents at junctions. To estimate the impacts of this on road safety, one must first estimate how many accidents or injuries will be influenced by converting a certain number of junctions to roundabouts. One way of doing this is to apply the following model:

\[
\text{Expected number of injured road users influenced} = \text{Number of junctions converted} \cdot \text{Mean traffic volume} \cdot \text{Mean injury rate}
\]

Thus, in a recent road safety impact assessment for Norway (Elvik 2007), it was assumed that conversion of junctions to roundabouts would start by converting junctions with a high traffic volume and continue with junctions with less traffic. It was estimated that it would be cost-effective (i.e. marginal benefits would exceed marginal costs) to convert 460 three leg
junctions to roundabouts. The number of injured road users expected to be influenced by this was estimated as:

\[
\text{Expected number of injured road users influenced} = 460 \times 12349 \times 365 \times 10^{-6} \times 0.091 = 189
\]

The first four terms represent exposure; the last term is the mean injury rate per million entering vehicles in three leg junctions. In principle, there are at least three sources of uncertainty in this estimate:

1. Uncertainty with respect to how junctions that are candidates for conversion to roundabouts are distributed according to traffic volume,
2. Uncertainty with respect to the mean injury rate for three leg junctions before conversion to roundabouts,
3. Random variation in the actual number of injured road users in junctions that are converted to roundabouts.

If the number of injured road users is assumed to be a Poisson variable, the variance equals the expected number (in this case estimated as 189); the standard error is the square root of the variance. However, as shown by Fridstrøm et al. (1995) and Bijleveld (2005), the Poisson assumption is strictly speaking only valid for accidents, not for injured road users, since there must by definition be at least one injured person in each injury accident, and since injuries are not independent. Hence, the number of injured road users in a sample of accidents that occur at random will display over-dispersion.

3.2 Incomplete or inaccurate accident reporting in official statistics
The estimate given above of the number of injured road users that could be expected to be influenced by the introduction of a road safety measure applied an injury rate that was based on official accident statistics. However, accident reporting is incomplete and inaccurate in all countries (Elvik and Mysen 1999). The true number of injured road users influenced by a road safety measure will therefore be greater than the recorded number.

Hauer and Hakkert (1988) have shown how one can estimate the true number of accidents and the uncertainty of this estimate, provided the level of accident reporting and the variance of the level of accident reporting are known. Unfortunately, this knowledge is rarely likely to be available at the level of detail that is required for meaningful use of the corrections described by Hauer and Hakkert. Besides, the purpose of the models developed by Hauer and Hakkert is to estimate the true number of accidents, whereas what we would like to know is how incomplete accident reporting adds to the uncertainty of the recorded number of accidents. The reason why this is what we need to know, is that an assessment of the success or failure of a road safety programme will most likely be based on the recorded number of accidents, not on an estimate of the unknown true number of accidents. As an approximation, one may assume that the addition to uncertainty in the recorded number of accidents attributable to incomplete accident reporting is proportional to the ratio (variance of estimated true number of accidents/estimated true number of accidents).

3.3 Uncertain definition of target group of accidents or injuries
Most road safety measures are intended to influence a clearly defined target group of accidents or injuries. In some cases, however, the group of accidents actually influenced by a measure will not be identical to the formally defined target group. In such cases, prediction of effect based on a formally defined target group may deviate from the effect actually observed, normally by being too optimistic.
A case in point is the study of changes in motorcycle legislation in Great Britain by Broughton (1987). He evaluated the effects of banning learner motorcyclists from using motorcycles with an engine volume of more than 125 cubic centimetres. Before the ban was introduced, accidents involving learner motorcyclists riding large motorcycles represented about 13% of all injured motorcyclists and about 31% of all learner motorcyclists injured. If the ban was perfectly complied with, one would expect these accidents to be eliminated. What happened was that learner motorcyclists switched to smaller motorcycles. Accidents involving learner motorcyclists riding small motorcycles increased. As a result of this, the total number of accidents among learner motorcyclists was reduced by only 8%. This reduction was actually smaller than the reduction of accidents among experienced motorcyclists in the same period (11%).

A related case is presented by Wanvik (2009). His study evaluated the effect on accidents of road lighting. It has traditionally been assumed that road lighting only influences accidents in darkness; hence, accidents in daylight may serve as a comparison group in a before-and-after study. Relying on this assumption and using data for Dutch motorways, Wanvik estimated the effect of road lighting to an impressive 58% reduction of accidents in darkness. Lighting poles represent a new traffic hazard on lit roads. This particular hazard does not exist on unlit roads. Accidents in which vehicles strike lighting poles may occur all day and therefore influence the number of daytime accidents. When the estimate of effect is adjusted for this, the effect attributed to road lighting on Dutch motorways is reduced to a 51% reduction of accidents in darkness.

3.4 Random variation in effects of road safety measures
For most road safety measures that are included in national road safety programmes, there will be multiple estimates of effect based on several evaluation studies. Summary estimates of effect based on meta-analysis will sometimes be available. In that case, uncertainty attributable to random variation in the effects of a road safety measure can be estimated by taking the inverse value of the fixed-effects statistical weight of the summary estimate of effect. This will indicate the purely random variation in effects around the summary effect.

If summary estimates of effect based on meta-analysis are not available, one may estimate the variance of an estimate of effect based on a single study by applying the techniques explained by Hauer (1997).

These approaches will not always be applicable, in particular not with respect to new road safety measures for which there may not be any evaluation studies that show effects on accidents and the uncertainty of those effects.

3.5 Unknown sources of systematic variation in effects of road safety measures
The effects of many road safety measures are likely to vary, depending on, for example, the standard of the measure (good road lighting is likely to be more effective than poor road lighting), the extent of its use (more police enforcement may be more effective than a little police enforcement), or the context in which it is introduced (a bypass road may be more effective in a small town than in a large town). Unfortunately, little is known about the sources and patterns of systematic variation in the effects of road safety measures. A fairly common situation may therefore be that there is known to be systematic variation in the effects of a road safety measure, as indicated for example by statistical tests made as part of meta-analyses, but that sources of this variation, and how best to model it, are unknown. This may lead to erroneous estimates of the effects of a road safety measure.

Figure 2 shows a case in point. It is based on a paper by Elvik (2009A) in which accident modification functions for the effects of bypass roads were developed. These functions were based on three evaluation studies reported in Denmark, Norway and Sweden, employing
broadly speaking the same study design. The effects of bypass roads were found to vary according to the size of the population of the bypassed town.

![Diagram](image)

Figure 2: Systematic variation in effects on accidents of bypass roads. Source: Elvik 2009A

If the variation in the effects of bypass roads had been unknown, the effect of building a new bypass road would have been predicted by applying a constant accident modification factor, shown by the straight line in figure 2. It can be seen that this would have given too pessimistic predictions for small towns and too optimistic predictions for larger towns. Fitting an accident modification function allows the predicted effect of a new bypass road to vary according to the size of the town. Yet, even these predictions are uncertain, as indicated in Figure 2 by the dotted curves showing the most optimistic and the most pessimistic of the accident modification functions that were developed in the study.

3.6 Unknown duration or stability over time of the effects of a road safety measure

Do the effects of a road safety measure gradually disappear as time goes by after its introduction? Or do the effects of introducing a road safety measure change over time? This may sound as two versions of the same question, but it is actually two different questions.

The first question is whether the effect on accident of, say, a roundabout are the same 10 years after it was built as during the first year. The second question is whether new roundabouts built today have larger or smaller effects during their first year than roundabouts built fifteen years ago.

Very little is known about these questions. There is, however, scattered evidence from a few studies suggesting that the effects of a certain road safety measure may indeed change over time. Elvik, Christensen and Fjeld Olsen (2003) reviewed studies of the effects of daytime running lights on cars. Five studies permitted these effects to be evaluated for different lengths of the after-period (i.e. after the use of daytime running lights became mandatory). Three of the five studies indicated that effects declined over time; one study was inconclusive;
one study indicated that effects increased over time. On balance, these studies suggest that it is more likely that effects are weakened over time than that they are strengthened.

A second example is given in Figure 3. Figure 3 shows the summary estimates of converting junctions to roundabouts based on evaluation studies reported in Norway. The first estimate is based on the first study reported in Norway; the second on the first two studies, and so on. At first, the effects on injury accidents of converting junctions to roundabouts seemed to increase. From the first five studies onwards, however, effects have become smaller as each new study has been reported.

![Figure 3: Summary estimates of effects on injury accidents of converting junctions to roundabouts](image)

The addition of the ninth study to the sample of studies was even associated with an increase of the size of the confidence interval for the summary estimate of effect. The width of the 95% confidence interval for the summary estimate of effect based on the first eight studies was 0.157 (0.557 minus 0.400). When the ninth study was added, the width of the confidence interval increased to 0.166. Apparently, it is not always the case that adding new studies makes estimates of effect more precise.

To statistically estimate and account for the uncertainty resulting from variation of the effects of road safety measures over time, it is necessary to predict the future effects of road safety measures. This cannot be done with any confidence, as shown by Elvik (1996).

3.7 Uncertainty regarding the combined effects of several measures
A national road safety programme normally consists of a large number of road safety measures. A recent road safety impact assessment for Norway, for example (Elvik 2007), included 45 road safety measures. A problem that needs be addressed in any road safety programme is how best to estimate the combined effects of the measures that form a programme. This cannot be done simply by adding the estimates of effect developed for each road safety measure. If three road safety measures influence the same target group of accidents, and are
expected to reduce accidents by 50 %, 40 % and 30 %, their combined effects cannot possibly be 120 %. Effects combine multiplicatively, not additively.

In a recent paper, Elvik (2009B) reviewed the very few studies that provide evidence about the combined effects of several road safety measures. Two models were developed to statistically estimate the combined effects of road safety measures. One of these models, labelled the common residuals model, assumes that the percentage effects of a road safety measure remains unchanged when the measure is combined with one or more other measures. Another model, labelled the dominant common residuals model, assumed that in any set of road safety measures, there will be one or more measures that are “dominant” in the sense that once they have been introduced, the effects of the remaining measures are weakened.

Exploratory analyses indicated that both these models can be defended and that no model appears to be clearly superior to the other. In general, the dominant common residuals model will give more conservative estimates of the combined effects of road safety measures than the common residuals model. There will, accordingly, always be uncertainty regarding the combined effects of all measures that form a road safety programme.

3.8 Uncertainty regarding the effects of exogenous factors
A road safety programme will typically apply to a period of 5-15 years. Although the programme may significantly influence road safety during this period, it will never be the only factor that influences road safety and may not be the most important factor. The outcomes that are observed in terms of the count of fatalities, injured road users and accidents, will be the result of all factors that influence road safety, not just the road safety programme.

When developing a road safety programme, it is essential to identify as precisely as possible the influence it will have on road safety, given the effects of all other factors influencing road safety. This is sometimes done by developing a so called baseline scenario, in which road safety is predicted assuming that the programme is not introduced. Once a baseline forecast has been made, the difference a road safety programme can make is estimated.

Although this sounds analytically straightforward, it is actually almost impossible to do in practice. Ideally speaking, the baseline scenario is intended to show what will happen if no road safety programme is introduced. Past trends in road safety give no information about this. Past trends reflect all factors that have influenced road safety, including all road safety measures that were introduced in the past. Hence, projecting past trends to the future does not show what might happen in a baseline scenario; it rather shows what might happen if road safety measures (and other factors) continue to be introduced at the same rate as in the past and continue to be equally effective.

Projecting past trends is a notoriously unreliable method for predicting future changes (Elvik 2010). Trying to identify factors that explain past trends does not help very much; in fact it makes prediction considerably more complex, since the explanatory factors have to be predicted in order to predict safety outcomes. While some factors that have influenced past trends may be identified (Elvik et al. 2009), this cannot be done in a very rigorous manner and may be of little help in predicting future changes.

3.9 Uncertain degree of implementation of road safety measures
Road safety programmes are almost never fully implemented. Estimates of their effects assume full implementation. When implementation is less than one hundred percent, effects on road safety will be reduced accordingly. In Norway, a system for long-term planning of road investments was created around 1970; the basic elements of this system are still in place. Fairly detailed investment programmes are developed every four years. At the end of the period, an assessment is made of the extent to which the investment programme has been implemented.
The first of these assessments, referring to the 1970-1973 planning term, was reported in 1973 (Samferdselsdepartementet 1973). It showed that 96.6% of planned investments had been implemented. The degree of implementation has subsequently declined. For the 1978-1981 term (Samferdselsdepartementet 1981), it was down to 92.9%. For the 1994-1997 planning term (Samferdselsdepartementet 1997), 92.7% of planned investments actually took place, and only 81% of the targeted effect on accidents was realised.

Estimates of effect obviously tend to be based on an assumption of 100% implementation. This will in nearly all cases be too optimistic, although the actual degree of implementation of a plan can never be predicted with much confidence.

3.10 Uncertain monetary valuation of impacts of road safety measures

All sources of uncertainty discussed so far, refer to uncertainty about the impacts of a road safety programme stated in terms of changes in the number of accidents or the number of road users killed or injured. The title of the paper, however, refers to the benefits of road safety programmes, not to their effects on accidents or injuries. What is the difference, and why has the term benefits been introduced?

The difference between the impacts of a road safety programme and the benefits of the programme is that the latter term refers to the conversion of all impacts of the programme to monetary terms. It is not uncommon that cost-benefit analyses of road safety measures are performed as part of the development of a road safety programme, in order to identify the road safety measures that are most cost-effective in improving road safety. The priorities given to the various road safety measures may not always be based strictly on the results of cost-benefit analyses. In principle, however, cost-benefit analyses can be used to determine the optimal use of each road safety measure and the optimal overall level of road safety.

If policy makers have an ambition of using cost-benefit analyses to determine the optimal level of safety, uncertainty about the monetary valuation of impacts becomes crucial. The monetary valuation both of road safety impacts, as well as other relevant impacts of a programme, like impacts on travel time, is highly uncertain (de Blaeij et al. 2003). It is therefore not possible to determine the optimal level of safety very precisely, if at all. Depending on how uncertainty with respect to monetary valuation is treated analytically, there can be a narrow or a broad range of outcomes that will be regarded as representing an optimal level of safety. The optimal size of budget may also vary considerably depending on the monetary valuations adopted.

4 THE BASIC MODEL FOR THE PROPAGATION OF ERRORS

The problem facing a policy maker who wants to quantify the uncertainty associated with the impacts and benefits of a road safety programme is how to estimate the combined contribution of several sources of uncertainty. A general answer to this problem can be found in statistics, in which the basic model for the propagation of errors has been developed (Rasmussen 1964, Sverdrup 1964). Assume that the outcome of interest can be modelled as a function of several variables:

\[ Y = f(X, Z, ..., W) \]  

Please note that all elementary arithmetical operations (adding, subtracting, multiplying, dividing), can be treated as functions. A random variable is also, by definition, a function. If the variance of each term entering a function (e.g. each of two numbers that are added) is independent of the variance of the other terms, the variance of the outcome equals:
\[ \text{Var}(R) = \left( \frac{\partial R}{\partial X} \right)^2 \text{Var}(X) + \left( \frac{\partial R}{\partial Y} \right)^2 \text{Var}(Y) + \ldots + \left( \frac{\partial R}{\partial W} \right)^2 \text{Var}(W) \] (2)

In equation 2, \( \frac{\partial R}{\partial X}, \ldots \) denote the partial derivatives of the function \( R \) with respect to the variables \( X, Y, \ldots, W \). \( \text{Var}(X, Y, \ldots, W) \) is the variance of each of the variables entering the function. It is well known (Strand 1987) that if the variances of the independent variables entering a function are correlated, the model for the propagation of errors becomes considerably more complicated. In this paper, only the elementary form of the model will be considered.

Estimating the benefits of a road safety programme can be modelled as a set of successive multiplications. At the first stage, the number of road users influenced by a road safety measure is obtained by multiplying exposure and injury rate for each level of implementation of each road safety measure. That level could, as an example, be to convert all junctions to roundabouts if the benefits of doing so exceed the costs. The next stage is to estimate the number of injuries prevented by a measure, by multiplying the number of injured road users in the target group by an accident modification factor or accident modification function. The economic benefit associated with each measure is obtained by multiplying the number of injuries prevented at each level of severity by the appropriate monetary valuation of preventing those injuries. Finally, the combined effects of a set of measures can also be obtained by multiplying the “residual factors” of the measures, i.e. the fraction of injuries in the target group that is not prevented by a measure. In the multiplication \( R = A \cdot B \), the partial derivatives are:

\[
\frac{\partial R}{\partial A} = B \quad \text{and} \quad \frac{\partial R}{\partial B} = A
\]

A and B are interpreted as random variables. This makes estimation of compound uncertainty easy, by proceeding in stages term by term.

5 QUANTIFYING EACH SOURCE OF UNCERTAINTY

To what extent is it possible to meaningfully quantify each of the sources of uncertainty discussed in section 3 of the paper? Table 1 gives a summary of the possibilities of quantifying the various sources of uncertainty.

As can be seen from the table, it is possible to quantify five of the ten sources of uncertainty discussed in this paper. For the other five sources, quantification of uncertainty is not possible at the current stage of knowledge. This obviously means that any estimate of the uncertainty associated with the benefits of a road safety programme will be incomplete and is bound to understimate the true uncertainty.

Uncertainty attributable to random variation of the number of injured road users influenced by a road safety measure can be quantified according to closed-form expressions developed by Bijleveld (2005). Hauer and Hakker (1988) give formulas for estimating the uncertainty associated with incomplete accident reporting. Random variation in the effects of a road safety measure can be quantified either by relying on statistical weights assigned to studies in meta-analysis or by applying formulas given by Hauer (1997). If there is reason to believe that there are unknown sources of systematic variation in effects, uncertainty attributable to this can be quantified either by relying on random effects weights in meta-analysis, or by applying the approach of Ye and Lord (2009). Finally, uncertainty with respect to the monetary valuation of safety benefits can be estimated by relying on, for example, the standard errors reported by de Blaey et al. (2003).
Table 1: Possibilities for quantifying sources of uncertainty in estimated benefits of road safety programmes

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<th>Source of uncertainty</th>
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<tr>
<td>1: Random variation in target group</td>
<td>Can be quantified using Poisson assumption for accidents and the estimator developed by Bijleveld (2005) for accident victims</td>
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<tr>
<td>2: Incomplete accident reporting</td>
<td>Can be quantified using estimators developed by Hauer and Hakkert (1988)</td>
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<tr>
<td>3: Uncertain definition of target group</td>
<td>Cannot be quantified at the current stage of knowledge</td>
</tr>
<tr>
<td>4: Random variation in effect of measures</td>
<td>Can be quantified by relying on fixed-effects statistical weights for summary estimates based on meta-analysis or by applying estimators developed by Hauer (1997) for single studies</td>
</tr>
<tr>
<td>5: Systematic variation in effect of measures</td>
<td>Can be quantified by relying on random-effects statistical weights for summary estimates based on meta-analysis or by applying estimators developed by Ye and Lord (2009) for single studies</td>
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<tr>
<td>6: Uncertain duration of effects</td>
<td>Cannot be quantified at the current stage of knowledge</td>
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<td>7: Uncertainty in combined effects</td>
<td>Cannot be quantified at the current stage of knowledge</td>
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<td>8: Uncertain effects of exogenous factors</td>
<td>Cannot be quantified at the current stage of knowledge</td>
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<tr>
<td>9: Uncertain degree of implementation</td>
<td>Cannot be quantified at the current stage of knowledge</td>
</tr>
<tr>
<td>10: Uncertain monetary valuation</td>
<td>Can be quantified by relying on standard errors reported in meta-analysis by de Blaeij et al (2003)</td>
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Uncertainty with respect to the definition of the target group of accidents or injuries influenced by a certain road safety measure is basically not of a statistical nature and is not sufficiently well-known at present to be quantified. While examples can be given of this source of uncertainty, no systematic knowledge exists. A similar point of view applies to uncertainty regarding the duration or stability over time of the effects of a road safety measure. Again, examples of a lack of stability can be given, but there is no systematic knowledge. As far as the combined effects of several measures are concerned, there is reason to believe that the effects of road safety measures may indeed be modified when combined with other measures. However, knowledge is too sketchy and incomplete to support any meaningful quantification of uncertainty. Uncertainty regarding the effects of exogenous factors and forecasts of safety is likely to be large, but not possible to quantify with any confidence. The same point of view applies to uncertainty regarding the extent to which road safety programmes are implemented.

6 CASE ILLUSTRATIONS OF QUANTIFYING UNCERTAINTY

6.1 Variance of the number of victims
Three examples will be given to show how uncertainty can be quantified. The first example deals with variance of the number of accident victims. In the numerical example given in section 3, 189 road users were injured annually in a total of 460 junctions that were considered for conversion to roundabouts. On the average, 1.4 road users are injured in each injury accident in junctions. It can thus be estimated that the 189 injured road users were injured in 189/1.4 = 135 injury accidents.

It may be convenient to represent the excessive number of victims per accidents, 0.4 (1.4 – 1.0) as a Poisson variable with a mean of 0.4. It can then be estimated that there will be a single victim (i.e. no excessive victims) in 90.2 accidents, 2 victims in 36.4 accidents, 3 victims in 7.3 accidents and 4 victims in 1 accident. 90 victims are expected to be injured in accidents involving only 1 victim, 73 victims in accidents involving 2 victims, 22 victims in acci-
dents involving 3 victims and 4 victims in accidents involving 4 victims. According to Bijleveld (2005), the variance of the number of victims can be estimated by:

\[ \text{Var}(V) = \sum_i v_i \]

\( N \) is the number of accidents, \( v_i \) is the number of victims in the \( i \)-th accident. In the present case, variance becomes:

\[(90.2 \cdot 1) + (36.4 \cdot 4) + (7.3 \cdot 9) + (1.0 \cdot 16) = 317\]

The first parenthesis is the number of accidents with 1 victim per accident. The second parenthesis is the number of accidents with 2 victims per accident; \( 4 = 2^2 \). The third parenthesis represents accidents with 3 victims; the fourth parenthesis is accidents with 4 victims. The number of victims in total is 189 and the variance of this number is 317 – rather more than what the simple Poisson assumption would imply (189).

6.2 Accounting for sources of variance in estimate of effect of a road safety measure

In an analysis of road safety policy in Sweden, Elvik and Amundsen (2000) compared three summary estimates of the effect on accidents of traffic calming:
1. One estimate accounting only for random variation in effect, obtained by using fixed-effects statistical weights in a meta-analysis of 32 studies that evaluated the effects in accidents of traffic calming,
2. One estimate accounting both for random variation and unknown sources of systematic variation in effects, obtained by relying on random-effects weights the same meta-analysis of 32 studies,
3. One estimate accounting for (a) random variation in effects; (b) unknown sources of systematic variation in effects and (c) incomplete accident reporting, obtained by relying on a study (Elvik and Mysen 1999) showing the mean level of accident reporting in the countries that had contributed the studies that were included in the meta-analysis.

Accounting for random variation in effects only, the summary accident modification factor for injury accidents was 0.855 (i.e. 14.5 % accident reduction) with a 95 % confidence interval from 0.881 to 0.830. When in addition systematic variation in effects was accounted for, the summary accident modification factor remained 0.855, but the 95 % confidence interval now spanned from 0.900 to 0.813. Finally, accounting for incomplete accident reporting resulted in a summary accident modification factor of 0.853 and a 95 % confidence interval from 0.935 to 0.778.

6.3 Uncertainty in the summary estimate of effect of a road safety programme

The uncertainty of the summary effect of a road safety programme is a function of all the sources of uncertainty discussed in this paper. As noted above, it is at the current stage of knowledge not possible to quantify the contribution of all these sources. It is, however, possible to provide a lower bound for the uncertainty of the summary effect of a road safety programme. Such an estimate was provided in a recent road safety impact assessment for Norway (Elvik 2007).

The reference value for the number of fatalities – the number expected to occur in 2020 if no new road safety measures are introduced – is 285. The variance of this number is about 335. The variance of the estimated reduction of the number of fatalities in each policy option
can be estimated by applying a fixed effects weight to the estimate, the way this is done in meta-analysis. The variance of an estimate of effect is the inverse value of the statistical weight assigned to that estimate.

If, for the purposes of gaining an impression of the uncertainty, the estimated, predicted numbers of fatalities are treated as if they were observed numbers, we get for policy option 1, optimal use of road safety measures:

Initial number of fatalities (“before treatment”) = 285
Final number of fatalities (“after treatment”) = 138

Statistical weight = \( \frac{1}{285} + \frac{1}{138} = 93.55 \)

Inverse of statistical weight = \( \frac{1}{285} + \frac{1}{138} = 0.0108 \)

We now have the following input values to estimate uncertainty with respect to the effect of this policy option on the number of fatalities:

Number of fatalities affected by policy option (A): 285
Variance of number of fatalities affected by policy option (Var(A)): 335
Estimated effect of policy option (B): 0.5128
Variance of effect of policy option (Var(B)): 0.0108
Number of fatalities prevented by policy option (A · B): 147
Estimate of variance of number of fatalities prevented:

\[
[(0.5128 \cdot 0.5128) \cdot 335] + [(285 \cdot 285) \cdot 0.0108] = 962.71
\]

The standard error of the number of fatalities prevented is the square root of the variance, which equals 31.0. Thus, for policy option 1, a 95 % prediction interval for the number of fatalities prevented is:

\[
147 \pm 1.96 \cdot 31.0 = 147 \pm 60.8 = \text{lower limit} = 86; \text{ upper limit} = 208
\]

7 DISCUSSION
Road safety policy is made in great uncertainty. It is not always perfectly clear which group of accidents or road users a road safety measure influences. Estimates of the effects of road safety measures are always uncertain; the more so when several measures are combined in a programme. The monetary valuation of the benefits of road safety measures is highly uncertain; thus it may not be possible to determine the optimal level of safety. No road safety programme can accomplish more than marginally influencing road safety; road safety is influenced by a host of factors that are beyond the control of any national, not to say local, government.

All these observations are perfectly obvious. It is therefore surprising that uncertainty is hardly mentioned in road safety programmes and that no attempt is made to identify the most important sources of uncertainty. This paper is a first step in that direction. The contribution of this paper is very modest; it has only identified the most important sources of uncertainty, briefly described them and indicated how they can be estimated statistically.

Five of the ten sources of uncertainty that have been discussed can be quantified at present; the other five remain difficult to quantify. Is there any prospect of quantifying these sources of uncertainty? It should be possible to quantify at least two of the five sources of uncertainty so far not quantified. Uncertainty with respect to the effects of exogenous factors (i.e. all other
factors influencing road safety in addition to the programme) can be approximately quantified by analysing the prediction errors associated with past predictions of changes in road safety. Uncertainty about the degree to which a road safety programme is implemented can be estimated by studying historical records showing the degree to which programmes were implemented in the past and variability with respect to the degree of implementation.

Research is often justified in terms of its contribution to reducing uncertainty. As far as the sources of uncertainty in the estimated benefits of road safety programmes are concerned, it is, however, not clear that more research will reduce uncertainty. In the first place, as shown by the example concerning the stability over time of the effects of road safety measures, new research may increase uncertainty by showing that effects previously thought to be stable over time are unstable. In the second place, the more sources of uncertainty that are quantified, the larger will be the estimated uncertainty. It is essential to remember that it is only the apparent uncertainty that has increased. True uncertainty may not have increased, but only become more correctly estimated.

8 CONCLUSIONS
The main results of the study reported in this paper can be summarised as follows.

1. The targets for improving road safety as part of national road safety programmes are not always realised. One reason for this may be that sources of uncertainty in the estimated impacts of such programmes are overlooked.

2. Ten sources of uncertainty in estimated benefits of national road safety programmes are identified and described. It is concluded that five of these sources can be quantified, whereas too little is known to quantify the other five sources of uncertainty.

3. Uncertainty with respect to the impacts of road safety programmes is rarely estimated, but is likely to be considerable.

4. More research on sources of uncertainty in road safety programmes may lead to the quantification of more sources of uncertainty, but it is unlikely that all sources of uncertainty can ever be meaningfully quantified.

REFERENCES
Bijleveld, F. D. (2005). The covariance between the number of accidents and the number of victims in multivariate analysis of accident related outcomes. Accident Analysis and Prevention, 37, 591-600.


ABSTRACT
As frequently argued, traffic victims will be higher and higher, at least in the short and medium terms, specially in developing countries. A recent report by the International Monetary Fund stated that the world economy is expected to continue to grow robustly by 4.9% in both 2007 and 2008, and that emerging markets and developing countries will continue to grow strongly [IMF, 2007]. Moreover, the close relationship between economic prosperity and increasing motorization and mobility, and between the latter and higher rates of traffic victims have also been proved [WHO, 2004]. Thus (since developing countries will certainly have to deal with a harsh burden of many traffic victims over the next years) the importance of answering “which first world answers may fit third world problems?”. Yet, two other fundamental issues must be deemed: “which are the priorities for those answers for each nation?”, and “have the first measures been successfully managed so as to step on to the next actions within the strategic plan?”. In this regards, a paper presented at the 13th RS4C Conference discussed the reasons that lead to the past and present absence of reliable and periodic road crash data in Argentina, without which none of the above questions could be answered properly [ZINI, 2005].

In this paper a complementary method to assess which first world answers can fit Argentina’s problems is proposed. A comprehensive, accurate and periodically updated road crash data base is essential to determine the priorities and the results of each measure, and therefore to design any efficacious strategic plan. However, as it is argued in quality management methods, priorities to prevent non-desired outcomes can be established from the analysis of the risks associated to any process. There are many advantages of this approach, namely that analyzing root causes rather than symptoms should generate better findings, or that many functionaries may feel more comfortable when managing risk indexes rather than hard facts that could lessen their administration performance, among many others.

Finally, as traffic and its victims are an extremely complex issue, a systemic approach will be adopted. This approach (opposite to one from a reductionism point of view) will prove to be suitable for a phenomenon that involves many human activities as well as complex interactions with a variable and sometimes unpredictable environment. To conclude, as explained in the last RS4C Conference, where, how and where are people killed or injured in traffic in Argentina cannot be determined with an appropriate precision. Therefore, an introduction to the way to estimate where, how and when there are higher probabilities for traffic victims to appear will be exposed.

1 INTRODUCTION
“For the times they are a-changin’”, repeated Bob Dylan several times in one of his most famous songs. Those lyrics were particularly special for the young people, since they expressed what most of them thought, and could not tell their parents. “The times they are a-changin” became an anthem of the ‘60s, and has since them been an inspiration for those who wanted to say something most of the people denied or just wouldn’t want to see. So what does this
has to do with traffic safety? It can be argued that over the past few decades something crucial has changed in how traffic victims are seen. On the one hand, many people are now aware that traffic injuries are one of the main causes of death around the world, affecting specially low-income countries, and affecting the humblest within every country. Therefore, many efforts to mitigate this heavy burden are done everywhere around the world, surely more than ever. On the other hand, the analysis of the many phenomenons that lead to a traffic injury has shown that they are too complex to concentrate the blame exclusively on the driver. Auspiciously, experts and decision makers around the world have understood that the driver cannot be indicated as the unique root of all evil in regards of traffic victims. This vision is not completely new, as in the sixties, sometime before Dylan started singing the above mentioned song, and when traffic victims where an almost exclusive problem of rich nations, the head of the Federal Highway Administration of the United States said:

"I am worried about the magnitude of the energies that are devoted to the aggressive effort to change the driver; to intimidate him or to embarrass him so that he will perfect himself. I believe that we have exhausted the value of this continuous attack to human nature. And I have serious doubts that this will produce any results. In many occasions, have not we tossed on the driver's shoulders a task that is beyond his senses, nerves and muscles? I believe that because of these attacks our attention is distracted, and our energy is deviated from the essential things that we could make to reduce the number of victims in road accidents. We should frankly face the premise that most of the drivers behave as well as it is reasonable to expect under the existent conditions. From that premise it is logical to deduce that the conditions should be modified. The road, the vehicle and the basic control measures of the system should be improved." [NADER, 1965]

Almost 25 years after this speech Sweden’s Vision Zero also recognizes that any efficacious strategic plan should contemplate the many aspects of traffic injuries that interact in this system, for example, human tolerance:

"The most important part of the vision and the meaning of 'Vision Zero' is that "no foreseeable accident should be more severe than the tolerance of the human in order not to receive an injury that causes long term health loss". If a virtually safe system is going to be designed, either the harmful event must be eliminated, or it should not reach the limit of the human tolerance. In the Vision Zero concept, it is assumed that accidents cannot be totally avoided, hence the basis for this concept is built around the human tolerance for mechanical forces.” [TINGVALL; HAWORTH, 1999]

By the time Vision Zero was being designed, automobile makers begun paying particular attention to the results indicated by some independent consumer organizations which assessed the safety performance of the most popular cars, such as the New Car Assessment Program of the United States, Europe, Japan and Australia. Current impact ratings and pedestrian protection evaluations show that nowadays cars provoke fewer and less serious injuries than cars designed as close as 10 years ago. The mentioned examples—which show just a little part of the many improvements made in road safety—are mentioned to explain why present times can be considered the times of a systemic approach of traffic and its victims.

Unfortunately, the mentioned improvements took place mainly in developed countries. Low-income countries share not only the fact that most of traffic victims are produced there, but also the fact that this happens while no efficacious strategic plans are implemented. In the case of Argentina, another paper discussed the reasons that lead to the past and present absence of reliable and periodic road crash data in Argentina, without which no diagnosis can be made, and no measures can be neither properly designed nor properly evaluated [ZINI, 2005]. The mentioned paper also indicated some feasible actions that would allow reverting the situation of the absence of road safety hard facts in the short and medium term. It is the intention of this paper to discuss a complementary way in which road safety targets can be established while proper road safety data bases are generated.
This complementary way is sustained by the theory that every process can be analyzed using some or all of the tools of quality management to improve it. Modern quality theories predicate the advantages of anticipating the actual outcome by analyzing the any process inherent risks rather than waiting for the non desired outcome to appear. Under this premises it can be stated that if a good evaluation of the risks of the traffic system in Argentina is performed, a strategic plan could be designed without the presence of accurate data. It is very important to notice that the word “complementary” has been used, since it can be argued that hard facts should be gathered and managed correctly to verify the performance of the system.

Finally, this paper is not going to indicate the complete process that will lead to the appropriate risk assessment of road traffic in Argentina, but will indicate a general introduction to the manner in which this could be done. Additionally, it will consider some of the differences between Argentina and other countries that should be accounted, as many successful measures adopted in developed countries may fail in our particular context. To conclude, as explained in the last RS4C Conference, where, how and where are people killed or injured in traffic in Argentina cannot be determined with an appropriate precision. Therefore, an introduction to the way to estimate where, how and when there are higher probabilities for traffic victims to appear will be exposed.

2 TRAFFIC VICTIMS AS THE RESULT OF A PROCESS
In every process there are causes and effects. The relationships between the latter are often evaluated in a diagram called Ishikawa diagram (also known as cause-and-effect or fishbone diagram). This tool allows to watch in a simple diagram the relationships between the different aspects that affect the outcome. In the next sections, the main and some secondary factors leading to traffic victims will be discussed. In addition, a few examples of some issues that should be considered in Argentina as local factors which may not appear in developed countries will be shown.

2.1 Defining the main factors
In the regards of the causes that may lead traffic victims, seven main factors are here proposed:

i) vehicle: every means of transportation that may harm a human being while moving.
ii) person: everybody exposed to the risk of road traffic (pedestrians, drivers or occupants).
iii) infrastructure: every road and its surroundings, every urban facility used for traffic, every resource used for prevention and medical attention.
iv) legislation: every law regulating traffic, the vehicles and the persons involved in it.
v) enforcement: every action performed to control that the legislation is respected.
vi) knowledge: every piece of information the society holds about the way in which injuries to traffic victims can be prevented or minimized.
vii) education: every way in which that knowledge is transferred to every character playing a role in road safety.

The mentioned factors that influence the generation of a traffic victim can be used as a starting point to analyze the numerous causes that interact in this complex process. Yet, another important segmentation must be done before going further. It can be argued that there are three different time-epochs in every road crash: the time before the crash takes place, the time during which the crash is happening, and the time after the crash finished.
It is clear that the relationships between every mentioned factor and that the influence of each of them in the final result is different, hence the need to separate the time epoch. Just to mention one example, it can be stated that a modern car traveling at 100 km/h presents a low risk to generate a crash and a subsequent victim. Experts concur on the fact that modern car are almost flawless in this respect. Yet, a car undergoing an impact at 100 km/h offers a kind of protection that is not enough to assure the complete protection of every occupant. Moreover, most cars experience a heavy deformation in high-speed impacts which makes the extrication of occupants very difficult, deferring their attention sometimes in a very decisive way. Therefore, if the proposed time segmentation is considered, it is easier to see that the car has little influence in generating a traffic victim before the crash, but that it has a clear influence in generating a traffic victim during and after the crash.

### 2.2 Defining the secondary factors

As said before this paper is not intended to explain the complete method, but it will show the process that should lead to the full analysis. Thus, the next step is to continue with the study of each factor in a matrix that takes time into account. Some examples of a second phase of the proposed analysis are the following:

#### i) vehicle

a. average age of vehicle population: *although modern cars allow a perfect control of the vehicle, old and inadequately maintained ones may generate traffic crashes.*

b. safety devices availability in vehicles: *it is true that safety devices have become very sophisticates, but not every vehicle has multiple airbags nor the latest impact-protection ones, so the protection offered to occupants should be evaluated from the actual availability of these devices and not from the potential availability.*

c. extrication capability of vehicles: *this, as explained above, should evaluate the extrication capability of the population of vehicles of the country where the analysis is being performed rather than from the better of cases.*

#### ii) person

a. population concern about own life: *it is clear that a population that shows little concern about its own life and about the life of other people will be more often in danger in a traffic environment than a mature and respectful population.*

b. gender of crash victim: *the gender of the crash victim has an influence on the result of the type and seriousness of injuries [HYDE, 1993].*

c. age of crash victim: *similarly, younger victims recover more fast and from more significant injuries than elder victims [HYDE, 1993].*

#### iii) infrastructure

a. general condition of roads: *poorly maintained roads may generate sudden changes of direction (to avoid cavities or gaps) that can lead to a road crash.*
b. proportion of two-way roads: two-way roads allow frontal collisions to take place, which are the most dangerous type of crash; hence, the higher the proportion of this roads, the more critical the crash.

c. distance from crash to nearest hospital: if the distance to the nearest medical facility is measured in the hundreds of kilometers, the chances for crash victims to survive unharmed reduce significantly.

iv) legislation
   a. driver license requirements: a country with little or no requirements for a driver license should expect an inadequate performance of drivers, hence higher rates of crashes.
   b. vehicle crash performance requirements: many of the crash performance improvements experienced by current design came from targets set by impact evaluation programs rather than from legislation requirements; in most low-income countries, airbags are not provided as a standard equipment of cars.
   c. affordable medical coverage for population: it is essential for a crash victim (who has generally undergone a violent event) to receive a proper medical attention which is out of the reach of most humble victims of low-income countries (who account for the majority of victims).

v) enforcement
   a. aleatory speeding control: it is vital for an effective enforcement that the population perceives it as aleatory and constant, in this way the behavior of the persons involved in traffic phenomena will be the one indicated by legislation for a greater period of time, and not only when they know they are being controlled.
   b. seat belt use control: speeding influences both the generation of a traffic crash and its outcome, but seat belt use is vital for preventing injuries once the impacts takes place, and should be widely and intensively controlled.
   c. fast control of crash surroundings: the way in which the police force can control the crash surroundings right after the impact is very important to recover vital information and to help the medical attention to get to the victims as soon as possible.

vi) knowledge
   a. traffic safety statistics: in this paper it has been already mentioned that a country should investigate its own problematic in order to define any appropriate strategic plan to minimize traffic victims.
   b. injury mechanisms research: injury mechanisms is still a field to uncover many mysteries, and the more it is known about it, the better the protection of the victims through better cars and infrastructure.
   c. injury recovery research: a minor injury can be converted into a serious one if the victims is not properly treated.

vii) education
   a. safety campaigns: the way in which population is made aware of the heavy burden traffic victims represent to the society and of the ways to minimize them is vital.
   b. helmet use campaigns: education can help minimize the outcome of a traffic crash, acting on a factor that interacts with the process during the crash.
   c. traffic trauma training: having surgeons that know exactly how to treat a traffic victim will generate higher rates of victims recovered.

The above list does not mean to be exhaustive, nor it will be expanded in this paper, since the scope of this essay is just to show the advantages of such a practice, and to explain the
general mechanism of analysis. Many hours and efforts should be put into the gathering of every piece of information that will lead to a proper diagnosis. Meanwhile, the mentioned secondary factors can be placed in Ishikawa’s diagram, as follows:

![Ishikawa’s Diagram]

**Figure 2:** A second version of Ishikawa’s diagram with a further level of detail in the analysis of the factors interacting to generate a traffic victim.

As the reader may notice, the complexity of the phenomenon is such that a multi-disciplinary task group is needed to complete the diagram. Sociologists, lawyers, education experts, police force administrators, road engineers, automobile engineers, among many others should work together in order to define each factor to an adequate level of detail.

### 2.3 Some examples of local factors that should be considered

A good example of how local factors can differ from other countries factors can be extracted from a very interesting report about the consensus among Swedish and non-Swedish traffic experts in regards to the priorities that should be given to a traffic safety strategic plan [NR&TR, 1998]. In the ranking made by European experts, the sixth place of the problem area was “road users do not follow the rules of the road”. Understandably, that problem did not rank in the eighteen-problem area list that the Swedish National Traffic Safety Program (Sveriges Nationella Trafiksäkerhetsprogram 1995-2000) established.

But, as indicated by the consulted European experts, not every nation bears the same respect towards Law. Particularly in developing countries, people disrespect towards Law is quite a complex issue, since Law and Enforcement are frequently associated with corruption and incompetence. Hence, in a traffic environment where order and rules are vital for the safety of the persons involved in it, the way in which people interact with local regulations and the ways in which this could be improved should be considered when trying to minimize traffic victims.
Another example of a factor that should be considered in Argentina is one that had a low priority in the mentioned report, and that is related to the vehicle’s ability to protect its occupants. Argentina does not share the same vehicle pattern as other developing countries, since every vehicle sold is either produced or imported by the main automobile manufacturers. There are no local designs that inherently underestimate safety standards.

However, local legislation is more permissive than European legislation (just to mention one) and for example new cars are not obligatorily delivered with frontal airbags as standard equipment. Therefore, a lower level of protection should be expected for occupants, when compared to European standards. In the regards of crash avoidance, a significant example can be mentioned. There are some new cars that are being sold without the third brake-lamp, which proved to be very useful an that is provided in every car in most countries. In Argentina, some versions of one of the most popular models, the Renault Clio, are provided without this safety feature. On top of that, in the specification of the mentioned vehicle, the third brake-lamps are considered a “design” feature. That is to say, for this particular brand of vehicles, a third brake-lamp
is a matter of how good-looking is the automobile, and not a matter of indicating the stopping of the car in a more safe way. Worst of all, this is not the only case of a modern Argentinean vehicle disregarding safety standards that are commonly adopted by the same models in other countries.

The last example of a factor that should be considered in Argentina is the presence of a new kind of urban pedestrian that pullulate in the big cities: the “cartonero”. These are very humble people living in the suburbs who walk throughout the city searching for valuable waste such as aluminium, glass or cardboard. As waste is gathered by night, the “cartoneros” (a group that includes little children and that are in a great proportion out of the Education system) enter the city when the sun sets, and walk many kilometers among the traffic, exposing themselves to high risks in bad-light conditions.

The three examples mentioned (lack of respect towards road rules, vehicles that are not as safe as the same models manufactured in Europe and pedestrians which cannot be easily educated in the dangers of traffic) should be considered as some of the many aspects that reflect the difference between first world traffic safety and developing countries traffic safety.

Image 2: A “cartonero” (person who gathers cardboard) mingling among the downtown traffic in Buenos Aires city [photographed by the author].

3 WEIGHTING EACH FACTOR
Completing the cause-and-effect diagram is a complex and multidisciplinary task. Yet, it is not enough to establish any priority within a strategic plan. The analyzed factors should be pondered and this weighting will indicate which of them represent higher risks and therefore which of them should be attended first. However, it can be argued that this procedure is also very complex and that it also requires a multidisciplinary group to be performed successfully.

Some differences between the relative weight of each factor can be outlined in a general way. For example, if a certain country does not perform injury recovery research it will have a greater risk than a country that knows how to properly recover a traffic victim. Similarly, if a country does not have accurate traffic statistics, it will also have a greater risk. Nevertheless,
injury recovery knowledge can eventually be transferred from developed countries into developing countries, while traffic statistics from Sweden or from the United States will prove to be of very little use in developing countries. Therefore, it can be concluded that not having a proper traffic data base is riskier from the generation of traffic victims point of view than not performing injury recovery research. Now, the difficult problem is to determine: how riskier? This will not be answered here, the question is proposed as to indicate that the reply to which is the greater risk will lead to a better assignments of priorities and resources. In the next two section an introduction to the way in which the factor could be weighted and to the way in which the relative importance could be presented will be discussed.

3.1 Defining each factor low and high points in a scale
There are many ways in which a phenomenon can be presented. A simple example of this will be given.

If the statistics from the United States are considered, two different conclusions can be extracted from a single figure: the number of fatal crashes. On the one hand, if the absolute figures are deemed, the number of fatal crashes have been growing steadily for the last decade. On the other hand, if the logical relative index “fatal crashes/traveled kilometers” is considered, the conclusion is different, and it can be said that the situation is getting better, since figures show a constant decrease in the same period. Anyhow, another conclusion can be made when comparing the number of fatal crashes with the number of total crashes: while the absolute total number of crashes shows a reduction, the absolute number of fatal crashes show an increment.

Therefore, it could be said that each crash is every time more serious, and, again, this could be an indication that the situation is getting worse. The above commentaries are destined to show that depending on the way in which an index is measured, different conclusions can be extracted. However, another important fact about what is being discussed is that higher levels of traveled kilometers will almost surely increase the absolute number of fatal crashes. A developing country with higher levels of economic activity will increment its mobility, thus augmenting the risk of traffic victims,

Figure 4: Absolute figures of fatal crashes in the United States show an increasing tendency [NHTSA, 2007]

Figure 5: Relative figures of fatal crashes in the United States show a decreasing tendency [NHTSA, 2007].
and this should be reflected in a clear way in the proposed risk assessment of this paper. Moreover, the notion “traveled kilometer” should be analyzed for each country, since an index that considers “vehicle traveled kilometer” will probably indicate a different evolution than an index that bears “person traveled kilometer”.

The scope of this section is not to determine the way in which the low and high point of each scale should be done for each factor, but only to mention that it must consider both the difference between absolute and relative measurements. And that if relative indexes should be considered, they must be constructed bearing the correct statistical population (“vehicle traveled kilometer” or “person traveled kilometer” in the mentioned example).

3.2 Estimating the risk value of each factor

Once the factor, the scale and the statistical population are defined, the risk value of each cause influencing traffic victims can be estimated. As the previous tasks, this one is very difficult and needs the participation of multidisciplinary groups. Most of the estimations should be done through sampling methods, yet factors will lack of the mentioned statistical population to ponder its risk. As an example, if the main factor “legislation” bears an identified risk that there is “some” heterogeneity between the different districts, a qualitative estimation of the risk importance should be performed, as a quantitative one is not applicable.

As in the last section, the scope of this one is again to introduce the discussion of some aspects that should be considered while constructing a risk index that can assess traffic safety.

3.3 Showing the evolution of the Risk Index

Figure 6: An example of how a series of radial charts can show the evolution of traffic risk.
The last issue to be considered about the risk assessment is the way to show its evolution. As said before, factors should be weighted to indicate their relative importance and the general situation of traffic safety. Yet, the more complete the information, the better the conclusions obtained from it. The above figure shows how the seven main factors are show altogether in a single radial chart. In the particular example shown, the greater the area, the greater the risk, and the performance of each factor can be evaluated from its contribution to the increment of the area of the chart. Several other charts should be made for each factor (considering also every time-epoch, that is before, during and after the crash), showing every time greater level of detail.

To conclude, the setting of risk targets can be useful to design the necessary plan, and periodic updates of the index with the aide of hard facts obtained in regular traffic data bases will complete the essential steps to assess the evolution of both traffic safety and the way in which it is being improved.

4 CONCLUSIONS
This paper means to be an inspiration for people concerned with traffic victims. And particularly for people concerned with traffic victims in developing countries. The main theme of this 2007 RS4C Conference is the pros and cons of applied research done in the “North” to problems in the “South”. It has been said that those pros and cons cannot be evaluated without a proper traffic data base and a diagnosis made from it. As in stated in a report about implementing Sweden’s Vision Zero, any successful decision-making process has to fulfil, among many others, the following conditions [NR&TR, 2001]:

– the goals for the reform work must be relatively unambiguous and not conflict too greatly with other important, societal objectives
– the decision-makers must have substantial knowledge about causes and effects within their field of work, especially concerning goals and the necessary measures to reach these goals

The proposed risk assessment should answer which fields of research can be applied to developing countries, should establish potential conflict with other societal objectives apart from traffic safety, and should increment the knowledge about the causes and effects within traffic victims. In this paper a very brief introduction to the theme has been presented, and it is its intention to encourage the discussion of the best way to implement it. The presentation of this proposal in an International Forum may also attire the attention of first world researcher who could propose alternative or complementary ways of action.

REFERENCES


ARE SPEED CAMERAS EFFECTIVE IN REDUCING ROAD CRASHES IN THE EMIRATE OF ABU DHABI?

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ABSTRACT
This study has evaluated the effectiveness of speed cameras in reducing the number of road crashes on a freeway road from Abu Dhabi to Al Ain in the Emirate of Abu Dhabi. Crash data has been collected for three years before the introduction of speed cameras and three years subsequently. The data was analyzed using “Before and After with Comparison Group” method. The common problems in ‘before and after’ studies such as regression to mean, maturation, and migration, were minimized through dividing the road into several sections. The road sections of approximately similar lengths and in close proximity to one another were compared. This study has found that speed cameras were effective in reducing the number of crashes on the Abu Dhabi to Al Ain road. Furthermore, it was found that the effectiveness of speed cameras was more on sections where the intensity of cameras was high. The study recommends that the deployment of more speed cameras in the Emirate of Abu Dhabi would help in improving the road safety.

Keywords: Speed camera, Road Safety, Regression to Mean, Before and After

1 INTRODUCTION
Driving speed is an important factor in road safety. Speed not only affects the severity of a crash, but is also related to the risk of being involved in a crash. Driving too fast for the prevailing traffic conditions is the single most significant factor in road crash fatalities in many countries (OECD, 2006). Excessive speeding is a common problem in the Emirate of Abu Dhabi. Abu Dhabi is one of the seven emirates that constitute the United Arab Emirates (UAE). According to traffic police officials, the most common cited traffic law violations is speeding and the culture of speeding in Abu Dhabi is so deeply rooted that drivers consider the speeding violation a normal offense. A review of the road crash statistics over a six year period (2001–2006) revealed that speeding contributed to more than 40% of fatal crashes in the Emirate of Abu Dhabi (Police reports, 2001-2006).

A number of researchers has reported that speed cameras hold a significant potential for reducing the speeding problem, and subsequently reducing the frequency of road crashes. For example, Elvik and Vaa (2004) reported that, based on a meta-analysis of studies related to evaluating the impact of speed cameras on road safety, in the period 1984-1996, automatic speed cameras helped to reduce the total number of road crashes by 19 percent. Other studies show very similar results (see Goldenbeld et al., 2005), and a few studies show even larger effects. For example, in Australia, an intensive speed enforcement program contributed to a 41 percent reduction in fatal road crashes. Similarly, in the UK, Gains et al. (2004) estimated a 42 percent reduction in fatalities or seriously injured casualties at the camera sites in response to the national safety camera program. A study by the OECD (2003) reported a 50
percent reduction in road crash fatalities at camera locations across Europe and reductions of 22 percent in New South Wales, 30 percent in all crashes on urban arterials in Victoria and 35 percent in serious road crash injuries at camera sites in the UK.

In another study Pilkington and Kinra (2005) reviewed 14 speed camera studies and concluded that existing research consistently shows that the installation of speed cameras is an effective tool in reducing road traffic crashes and related casualties. Pilkington and Kinra (2005) found reductions in crashes ranged between 5 and 69 percent; injuries fell between 12 – 65 percent; and deaths were reduced by 17 to 71 percent in the vicinity of the cameras. Similarly, Wilson et al. (2006), reviewed studies related to evaluating the impact of speed cameras on road safety, and noted that all the studies they examined showed reductions in crashes after the implementation of the automated speed enforcement program, with reductions ranging from 14 to 72 percent for all crashes within the vicinity of the camera site to 8 to 46 percent for injury crashes and 40 to 45 percent for crashes involving serious injuries or fatalities.

There are a number of other studies that have also reported evidence of the effectiveness of cameras in reducing speeding, for example in Washington, D.C. (District of Columbia, 2006) in New South Wales (Anderson and Edgar, 2003), in British Columbia (Chen et al., 2002), in New Zealand (Keall et al., 2001, 2002), in Norway (Retting et al., 1998) and in UK (Jones et al., 2008).

In the Emirate of Abu Dhabi, the installation of the speed cameras on freeways was started in 2000. The effectiveness of speed cameras in improving the road safety in the Middle East is not well known. Ali et al., reported in Webster, (2000) that speed cameras have not had the desired effect of reducing the speeding behavior of drivers in the oil rich nations of the Middle East. This study aims to assess the evidence for the effectiveness of speed cameras in reducing crashes on Abu Dhabi to Al Ain freeway.

2 METHOD

2.1 Data Collection
The crash data of six years (2001 to 2006) was collected from Abu Dhabi Police department for the freeway road (Abu Dhabi to Al Ain) which was selected as a case study. The geographical location of this road is shown in Figure 1. This road passes through a number of small towns including Al Mafraq, BaniYas, Al Wathba, Al Khatim, Al Khaznah, Remah, Abu Samarrah, Al Yahar, Al Salamat and Bateen. There are a few steep reverse horizontal curves closely spaced in areas including Khaznah, Remah, Al Yahar, and Al Salamat that implies an adverse geometric alignment in the proximity of these areas.

The exact locations of the crashes such as defined by the GPS coordinates were not available. However, the existing crash database provides information such as towns’ names that was used to estimate the approximate locations of the crashes. While, the locations of the speed cameras or cabins of cameras were fixed, and estimated by travelling from Abu Dhabi to Al Ain. According to Abu Dhabi Police speed cameras on this road were installed in 2003. The period from 2001 to 2003 was considered as before and period from 2004 to 2006 as after.
2.2 Data Analysis

The yearly crash data was separated by towns’ names. In order to compare before and after crash statistics the road under study was divided into sections of approximately similar lengths. The crash data for towns within sections were aggregated together. The aggregated crash data of the sections close to each other with different number of cameras were compared. Table 1 shows the sections, names of towns, lengths of sections, and number of speed cameras in each section. In addition, a simple before and after comparison of the number of crashes within each section is also presented in this table. It was found that the total number of crashes for all sections except section 8 was reduced after the introduction of the cameras. The reduction in the number of crashes can be attributed to multiple factors including installation of speed cameras, possible changes in the traffic volume and variations in the drivers’ characteristics.

The reduction in the number of crashes possibly attributed to the installation of speed cameras is assessed through using the “before and after with comparison group” method. This method has been widely used to estimate countermeasure effects in the road safety field (Mountain et al., 1992; Hauer 1997, Persaud 2001). In this method, the before and after crash statistics of the target road is compared with before and after crash statistics of a comparison road. The target road refers to a road where the effect of the speed cameras on reducing the number of crashes is to be determined. The comparison road refers to a road that has similar characteristics (such as speed limit, number of lanes, and road classification etc.) to the target road and where treatment such as speed cameras had not been made. It is reported in (Hauer, 1997, 1999, 2002) that the underlying assumption of this method is that the factors that affect road safety have changed in the same way from before to after period for both the target and comparison road, and the influence of changes in various factors on road safety is the same for both roads. These assumptions imply that the change in the number of crashes before and after the installation of speed cameras on the target road, if the cameras had not been installed, would have been in the same proportion as that for the comparison road. That is, without the installation of the cameras, the two roads would be expected to have similar crash levels in the after period. The strength of the study is directly proportional to how similar the target road is with the comparison road. Furthermore, this method helps in reducing the problems such as Regression-to-the-mean, crash migration, and maturation generally associated with the before and after methods (Griffin, 1982, Haur, 2002).
Table 1: Characteristics of sections and simple before and after comparison

<table>
<thead>
<tr>
<th>Section</th>
<th>Towns</th>
<th>Length (Km)</th>
<th>Number of speed cameras</th>
<th>Number of total crashes</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al-Maqtta Bridge Bein Eljesein Bridges complex Mussafah</td>
<td>11.7</td>
<td>2</td>
<td>86</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>Mohammed bin zayed city Muhawi Al-Mafraq</td>
<td>11.5</td>
<td>0</td>
<td>134</td>
<td>98</td>
</tr>
<tr>
<td>3</td>
<td>Bani Yas AL-Wathba</td>
<td>19.3</td>
<td>1</td>
<td>144</td>
<td>98</td>
</tr>
<tr>
<td>4</td>
<td>AL-Nahda Al Faya</td>
<td>19.1</td>
<td>1</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>AL-Khatim</td>
<td>21</td>
<td>2</td>
<td>52</td>
<td>33</td>
</tr>
<tr>
<td>6</td>
<td>AL-Khaznah</td>
<td>26</td>
<td>2</td>
<td>41</td>
<td>34</td>
</tr>
<tr>
<td>7</td>
<td>Remah Abu Samrah</td>
<td>22</td>
<td>2</td>
<td>76</td>
<td>67</td>
</tr>
<tr>
<td>8</td>
<td>AL-Yahar Salamat Bateen</td>
<td>21</td>
<td>1</td>
<td>28</td>
<td>41</td>
</tr>
</tbody>
</table>

The researchers, (for example, Pendleton, 1991 and 1996; Griffin, 1982, Haur, 1997, 1999) have proposed various formulas to estimate the effectiveness of a measure in the before-and-after with comparison group method. The mostly commonly used formula is as follows:

\[
CRF = \frac{OR - 1}{OR}
\]

Where,

\[
CRF = \text{Crash Reduction Factor}
\]

\[
OR = \text{Odds Ratio, a ratio between odds of before and after crashes in comparison group to odds of before and after crashes in treatment group}
\]

Odds Ratio can be calculated as follows:

\[
OR = \left(\frac{A}{B}\right) \div \left(\frac{C}{D}\right)
\]

Where,

\[
A = \text{Before crash counts for comparison road}
\]

\[
B = \text{After crash counts for comparison road}
\]

\[
C = \text{Before crash counts for target road}
\]

\[
D = \text{After crash counts for target road}
\]

The effectiveness of a treatment would depend on the CRF, for example a negative value of CRF would indicate that speed cameras are effective in improving road safety otherwise, treatment is ineffective (i.e. no reduction in number of road crashes due to treatment).
The 95% confidence interval (CI) of odds ratio can be estimated by the following formulas:

Upper limit of 95% CI of (OR) = \( e^{\ln(OR) + 1.96(1/A + 1/B + 1/C + 1/D)^{0.5}} \)

Lower limit of 95% CI of (OR) = \( e^{\ln(OR) - 1.96(1/A + 1/B + 1/C + 1/D)^{0.5}} \)

2.3 Results
In this study the road sections close to each other with similar characteristics and with approximately the same lengths are compared to each other. The road sections with a higher number of speed cameras than other sections were considered as the target group and the sections where either no camera or a lower number of cameras were considered as the comparison groups. The Crash Reduction Factors were calculated by using the formula described above. Table 2 presents the Odds Ratios, CRFs, and 95% Confidence intervals of Odds Ratios.

Table 2: Results of Before and After comparison method

<table>
<thead>
<tr>
<th>Section</th>
<th>A = Before crash counts for comparison section</th>
<th>B = After crash counts for comparison section</th>
<th>C = Before crash counts for target section</th>
<th>D = After crash counts for target section</th>
<th>Odds Ratio</th>
<th>Crash Reduction factor</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al Maqta bridge to Mussafah</td>
<td>134</td>
<td>98</td>
<td>86</td>
<td>57</td>
<td>0.91</td>
<td>-0.09</td>
<td>Effective treatment</td>
</tr>
<tr>
<td>Al Maqta bridge to Mussafah</td>
<td>144</td>
<td>98</td>
<td>86</td>
<td>57</td>
<td>0.97</td>
<td>-0.03</td>
<td>Effective treatment</td>
</tr>
<tr>
<td>AL-Khatim</td>
<td>144</td>
<td>98</td>
<td>52</td>
<td>33</td>
<td>0.93</td>
<td>-0.07</td>
<td>Effective treatment</td>
</tr>
<tr>
<td>Remah to Abu Samrah</td>
<td>28</td>
<td>41</td>
<td>76</td>
<td>67</td>
<td>0.6</td>
<td>-0.4</td>
<td>Effective treatment</td>
</tr>
<tr>
<td>AL-Khatim</td>
<td>17</td>
<td>13</td>
<td>52</td>
<td>33</td>
<td>0.83</td>
<td>-0.17</td>
<td>Effective treatment</td>
</tr>
<tr>
<td>Bani Yas to Al Wathba</td>
<td>134</td>
<td>98</td>
<td>144</td>
<td>98</td>
<td>0.93</td>
<td>-0.07</td>
<td>Effective treatment</td>
</tr>
</tbody>
</table>

The results presented in Table 2 indicate that speed cameras appear to be effective on target sections for reducing the number of crashes. For example, the CRF for the target section from Al Maqta bridge to Mussafah is -0.09 that reflects a 9% reduction in crashes in relation to the comparison section from Mohammed bin zayed city to Al Mafraq. It is noted that the intensity
of cameras influence the CRF. As the CRF is greater for the target sections where cameras are closely spaced than other sections where the cameras are more distantly spaced. For example, the sections from section 5 (Al Khatim) and section 7 (Remah to Abu Samrah) both contained more cameras than their respective comparison sections. This implies effectiveness of cameras could increase by reducing the spacing between cameras.

The comparison sections of Al Khatim and Al Khaznah both contained two cameras but the CRF (-0.23) revealed that cameras are more effective at Al Khatim than at Al Khaznah. One possible reason for this result is the difference in road geometry at these sections. The section Al Khaznah contains steep reverse curves while the section at Al Khatim is relatively straight. This would imply that the installation of speed cameras in the Al Khaznah section particularly before the steep curves might be able could help in reducing the crashes.

3 CONCLUSIONS AND RECOMMENDATIONS

In this study the effects of speed cameras on reducing the total number of crashes on the Abu Dhabi to Al Ain road was examined. Based on the study’s results, the main conclusions that can be drawn is that it appears that speed cameras were effective in reducing the crashes on the Abu Dhabi to Al Ain road. The study also found that increasing the intensity of cameras (i.e. reducing the space between cameras) would help in improving the effectiveness of speed reduction.

This study recommends that more speed cameras should be deployed to control the speeding behavior of drivers. In addition to installing more cameras other mechanisms of traffic surveillance should be investigated. For example, regular police patrols should be completed particularly on sections of roads with a high crash history. Surveillance by the police would help in detecting various types of traffic violations that cannot be detected by speed cameras, for example, tailgating, sudden deviations, and drunk-driving.

Acknowledgement

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REFERENCES
Pilkington, P and Kinra, S (2005). Effectiveness of speed cameras in preventing road traffic
http://bmj.com/cgi/doi/10.1136/bmj.38324.646574.AE
DEVELOPING A ROAD SAFETY STRATEGY FOR THE EMIRATE OF ABU DHABI

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ABSTRACT
It is widely acknowledge that road safety is most effectively delivered when the elements of Engineering, Enforcement and Education are combined and targeted towards delivering a challenging yet achievable target. The best way to achieved this is through the development and implementation of a Road Safety Strategy.

TRL have been appointed by the Department of Transport to develop a Road Safety Strategy for the Emirate of Abu Dhabi. The organisation of road safety is currently undergoing major changes in Abu Dhabi as several new government bodies have been created in the last two years. As these bodies are becoming established they are all undertaking a number of significant initiatives to develop and improve their approach to road safety. For this reason the timing of the development of this Strategy is very important as it will ensure that all of the developments are progressed in a controlled and coordinated manner towards a target of reducing road casualties.

Through this paper the Authors will detail how the Strategy was developed, how appropriate targets have been calculated and set and how an implementation programme has been developed. The paper will also highlight the lessons learned from the approach taken.

Please note that data for the Strategy is currently being collected and analysed. The final Strategy is due to be completed by the end of May 2010.
1 INTRODUCTION
It is widely acknowledge that road safety is most effectively delivered when the elements of Engineering, Enforcement and Education are combined and targeted towards delivering a challenging yet achievable target. The best way to achieve this is through the development and implementation of a Road Safety Strategy.

The Department of Transport is currently developing a Road Safety Strategy for the Emirate of Abu Dhabi. The organisation of road safety is currently undergoing major changes in Abu Dhabi as several new government bodies have been created in recent years. As these bodies are becoming established they are all undertaking a number of significant initiatives to develop and improve their approach to road safety. For this reason the timing of the development of this Strategy is very important. It will ensure that all of the developments are progressed in a controlled and coordinated manner to provide the synergy for a target focused approach to reducing road casualties.

Through this paper the Authors will detail how the Strategy is being developed, how appropriate targets will be calculated and set, and how an implementation programme will be developed. The paper will also highlight the lessons learned from the approach taken.

2 STRATEGY APPROACH
The aim of the Strategy is to reduce the number fatalities and casualties resulting from traffic collisions on the roads of the Emirate of Abu Dhabi. It is therefore important that the strategy should look to address all the factors that can contribute to road collisions.

Traffic collisions are primarily the result of a multiple causal events in which one or more users of the road network fail to cope with the prevailing conditions. Figure 1 (Treat et al. 1979) provides an illustration of the factors that could influence a collision.

![Diagram showing contributing factors to collisions.](image)

Figure 1: Contributing factors to collisions.

From this chart, it can be seen that the overwhelming contributory factor is the human factor of the road user whilst to a lesser extent the road environment and vehicle factors. For the reasons stated above, the road safety strategy must take a holistic approach to achieve the best possible results and will only be fully successful if it involves and is supported by all relevant stakeholders. No single organisation working in isolation is capable of providing an effective solution.

To develop the Strategy, the current organisational structure of road safety in Abu Dhabi was investigated thoroughly. Then, the current practices were compared to internationally recognised best practices, and finally improvement areas were identified and an
implementation plan was to be developed. The strategy was therefore developed in three stages:

- The first was a review of current conditions;
- The second was to identify and develop required improvements; and
- The third was the development of an implementation plan.

To undertake these tasks a team comprising of two elements was formed. The first element involved a small number of individuals based in country throughout the whole period of the review process. The second element was a larger team of specialist who have specific knowledge of world best practices in the areas they were tasked to review.

It should be noted that the review was still underway when this paper was written and the final strategy is not due to be completed until May 2010.

When comparisons are made to international best practice it is important to bear in mind the current performance of the country being reviewed and the performance of the comparison country. Significant casualty savings can be made in the short term if a number of standard road safety issues are addressed and improved. However, longer term and continual improvements can only be made by an expanded understanding of possible achievements and the development of innovative strategies and associated targets (OECD/ITF 2008). For example, in Abu Dhabi seat belt wearing rates are low and significant improvement in casualty severity could be achieved if wear rates were increased. Where as in western Europe seat belt wearing rates are very high and little further improvement can be made by increasing their use.

3 REVIEW OF CURRENT CONDITIONS

One of the key elements of the review was to identify the current strengths of the systems and processes stakeholders already have in place in Abu Dhabi and to identify what additional areas need to be targeted. To investigate the systems and processes and to identify the strengths and weaknesses the field of road safety was divided into seven sectors, as detailed below.

3.1 Subject areas to be reviewed

For the purpose of the review the road safety system was divided into the following sectors:

- **Road safety management and coordination**
  To ensure the effective delivery of the road safety strategy it will be necessary to have clear and strong management and coordination systems in place. To be fully successful the strategy will require the full support and coordination of all relevant stakeholders.

- **Road safety engineering**
  Although engineering has a limited overall effect on the number collisions that occur it can have a significant effect on the consequences of the collisions that do occur. Engineering changes can also result in very quick reductions in the number of collisions at specific locations.

- **Education and awareness**
  Education, particularly in schools, is a very important part of road safety, but it also needs to be supported by wider approach of education to the various groups of road users largely comprising of the travelling public. This includes pedestrians and driver training and testing. Of specific concern in the Emirate of Abu Dhabi is the high number and turnover of drivers and visitors from overseas. Local education and awareness systems needs to take this into account to ensure all drivers and pedestrians are aware of the local conditions on Abu Dhabi roads.
• **Enforcement**
  As human factors represent such a high proportion of the causes of collision causation enforcement is an integral factor in any road safety strategy. Coupled with education it can provide a significant contribution to affect driver behaviour and provide a sustainable improvement to road safety over time. To be effective however, enforcement must be targeted, understood and supported by society.

• **Vehicle safety and registration**
  Although vehicle factors represent the smallest sub section of the factors in a collision they are still involved in 13% of all collisions. As a result robust and enforced safe vehicle standards can have a significant effect on road safety.

• **Emergency and medical care**
  Where accidents occur, effective and well organised emergency medical care is critical to maximising casualty survival potential. The ‘golden hour’ is often quoted as the period following a crash that has the greatest influence on the possibility of an injured person, surviving and recovering, from their injuries. As a consequence emergency care of traffic collision victims is an integrated element of a safety strategy.

• **Evaluation**
  An essential, but often neglected road safety factor is the evaluation of interventions. Without robust and reliable evaluation it is not possible to determine whether their effectiveness is having a positive, or indeed an negative impact on road safety. The approach to evaluation needs to be carefully considered and often requires a range of carefully considered performance indicators to access underlying performance.

To evaluate the strengths and weaknesses of the current road safety performances in the Emirate of Abu Dhabi the following assessment process was undertaken.

3.2 Review process
The review process involved the following tasks:
- discussions with the stakeholders
- site visits
- reviewing existing policies
- reviewing available documentation
- reviewing current processes
- observation of working practices

The main element of the fact finding exercise was based around interviews with stakeholders. However, it proved to be equally important to review documentation and working practices to ensure that the information gathered through the interviews reflected what was happening in practice.

The interviews with the stakeholders involved four key elements. The first was an initial meeting with a high level member of the organisation. The purpose of this meeting was to gather preliminary data and to identify individuals within the stakeholder organisation that the visiting experts should interview.

The second element involved meetings between the visiting experts and the identified individuals. The purpose of these meetings was to gather as much information as possible about each stakeholder, their role and their relationship to road safety. Prior to each meeting the stakeholder was provided with a list of questions that enabled them to prepare for the interview. The questions investigated general areas related to road safety as well as specific
organisational responsibilities associated with the stakeholder or the subject area being investigated.

The third element was to review any documentation that the stakeholders made available and to make observations of actual working practices. This work was undertaken by the visiting experts and the purpose was to validate the information obtained during the interviews in the second element with what actually happened in practice.

The fourth and final element was to feedback the information gathered to the stakeholders to verify findings and observations.

In addition to the interviews, an Emphasis Areas report was also developed. This report was primarily data led and reviewed the current situation in the Emirate of Abu Dhabi, highlighting areas needed to be addressed through the strategy. A key factor element of the Emphasis Areas report was a detailed analysis of crash patterns in the Emirate. This information formed the basis upon which the development and successful implementation of the proposals will be based.

3.3 Review scoring

To assess strengths and identify areas for development, a review of relevant and available documents was undertaken and a consultation exercise with relevant stakeholders was held.

In order to make the assessment as objective as possible and provide a standard benchmark for the future, a set of performance indicators for each of the identified sectors was developed, as shown in Figure 2.

The current road safety situation in the Emirate of Abu Dhabi was assessed by providing a performance score for each of the key sectors. These scores are determined by considering a number of ‘Desired Conditions’ and more detailed ‘Indicators’ that should be present in an effective road safety system, as shown in Figure 3, full details are provided in appendix A.

Figure 2: Road safety sectors and sub-sectors
The importance of each sector was determined, based on extensive experience and research carried out in over 50 countries, and each sector was weighted by order of importance to the overall performance of the road safety system. Importantly, the weightings have also been adjusted to ensure that they are compatible and reflect the local conditions in Abu Dhabi.

The weightings have been constructed so that those given to each sector and to each sub-sector have a maximum value of 100. This weighting regime means that it is possible to provide a separate performance score for each individual sector and for the various detailed situations identified within that sector. Performance is measured on sector performance across the Emirate and does not and is not intended to reflect the performance of individual stakeholders.

This systematic method makes it possible to provide a numerical and objective measure of current performance. Importantly, the framework will also allow the stakeholders to very quickly determine the sectors and attributes which need improvement mostly and the potential for high benefit cost effective quick wins.

Each performance indicator has been given a weighting relative to its importance in the overall management of road safety. The score achieved is based on an assessment of the quality and quantity of any activity currently being carried out in the Emirate. Scores up to 100 will be given against each indicator according to how far it has been achieved. The scale used to achieve the marks is provided in Figure 4 below.
<table>
<thead>
<tr>
<th>Score</th>
<th>Current activity achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No activity or completely ineffective</td>
</tr>
<tr>
<td>1 - 20</td>
<td>Some activity but amount or quality insufficient for any safety impact.</td>
</tr>
<tr>
<td>21 – 40</td>
<td>Minor activity evident but major problems exist which considerably restrict impact</td>
</tr>
<tr>
<td>41 – 60</td>
<td>More activity evident but there are still some major drawbacks which reduce impact</td>
</tr>
<tr>
<td>61 – 80</td>
<td>Some effective activity is evident but there is still some significant improvement to be made</td>
</tr>
<tr>
<td>81 - 100</td>
<td>Activity is clearly effective and up to the standards found in the best countries</td>
</tr>
</tbody>
</table>

Figure 4: Performance scores

4 IDENTIFICATION AND DEVELOPMENT OF REQUIRED IMPROVEMENTS

The information gathered during the review process is currently being used to analyse the current road safety situation in Abu Dhabi and to assess it against international best practices, as detailed above. The assessment is providing an evidence based reflection of the existing holistic approach to road safety in Abu Dhabi. It will not include any proposed enhancements that are planned but have not yet been implemented or that had been in place for an insufficient period to make effective judgment of their respective contribution. Such enhancements were however recorded and an assessment of their respective future potential was considered.

For example, it is known that the current collision data available does not have sufficient location details to allow a detailed analysis of collision black spots on the network. However, it is also know that a new collision recording system that will automatically record the GPS co-ordinates of the collision scene is being implemented. It is hoped that after a trial period this system could then be rolled out throughout the entire Emirate. This is an initiative that will be incorporated into the overall improvement programme that will be developed.

The review is currently at the stage where the strengths and weaknesses are being assessed and a series of policies and proposals are being developed in the areas where strengthening is required, taking into account the findings of the Emphasis Areas report. The implementation plan will include an indication of the relative cost of the improvement work, an assessment of the relative effectiveness of the identified improvement, and an indication of the time frame needed for implementation.

The policies and proposals will be drawn together to form the first draft of the Strategic Road Safety Plan. In addition to identifying the improvement areas the Strategy will also look to address other areas, for example the cost of casualties in the Emirate and the development of key performance indicators to monitor the success of the Strategy during its implementation.

Following the completion of the draft Strategy, a workshop will be held with stakeholders to discuss the findings of the review and the proposed improvement measures. The importance of this workshop cannot be stressed enough as the successful implementation of the Strategy will depend on achieving the support and cooperation of the stakeholders. Due to
the holistic nature of the Strategy, without their support the effectiveness of the Strategy will be severely limited.

4.1 Cost of Casualties
Apart from the humanitarian aspect of reducing road deaths and injuries, a strong case can be made for reducing road crashes on economic grounds alone. They consume massive financial resources that any nation can ill afford to lose. It must of course be borne in mind that road safety is but one of the many problems demanding its share of funding and other resources. Even within the boundaries of the transport and highway sector, hard decisions have to be taken on the resources that any country can devote to road safety. In order to assist in this decision-making process, it is essential that a method is adopted to determine the cost of road accidents and the value of preventing them.

A study (Fouracre and Jacobs, 1977) estimated road accidents to cost on average 1 per cent of a country's gross national product (GNP) each year. This figure has been used by many countries and international aid agencies to estimate the scale of costs incurred by road crashes but as countries have developed, a higher range, 1 to 3 per cent has been suggested by the World Bank and others for the actual cost of road accidents. Understanding and valuing the lifetime economic cost to society of fatal incidents assists in understanding the actual financial losses sustained as a result of inadequate road safety measures. By understanding of economic loss improvement measures can be assessed, costed and cost benefit analysis provided for a range of improvement measures. Not only is there a moral responsibility for Government to ensure road safety there is an economic driver to assist with implementation.

4.2 Development of Targets
The development of key performance indicators are essential so that the progress of the strategy could be monitored and forward planning adapted if necessary at review points in the future.

The key performance indicators are yet to be developed, but they will be based on a challenging but achievable target of reducing road casualties by a calculated percentage by 2020. This target reduction will be based on an assessment of current casualty conditions and trends and realistic improvements that could be made over the ten year time period. The proposed improvements will then assessed to see how they would contribute to achieving the overall reduction. Following this assessment the key performance indicators will be developed to enable monitoring of the improvements to be made on a regular basis so that further interventions could be taken if the desired casualty reductions were not being achieved.

5 DEVELOPMENT OF IMPLEMENTATION PLAN
The overriding intention of this project is to ensure that a Road Safety Strategy that is realistic, coordinated, comprehensive, practical and integrated is developed and implemented. To ensure this is the case, it will be necessary to discuss the financing and timing of the proposed improvement projects with the stakeholders, who will ultimately be responsible for their respective implementation action plans. Furthermore, it is important to ensure that the planned policies and implementation programmes are integrated with the stakeholders existing policies, programmes and funding strategies.

It is currently intended that a five year implementation plan will be developed.
REFERENCES

APPENDIX A – Example of Management and Coordination sector scores

Table 1.1 Effectiveness score for Road Safety Management and Coordination

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinating committees and lead agencies</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coordinates planning, implementing and monitoring effectively</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meets regularly to discuss/coordinate road safety activity</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Key organizations all represented including NGO’s at senior level</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Members active and effective</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decisions implemented</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terms of reference and objectives stated</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road safety strategy/plan</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National &amp; City plans with safety targets and objectives</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear statement of National safety budgets</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political support National &amp; City</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior National politician responsible for overseeing safety</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government accepts safety is important issue requiring urgent attention</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal statement of responsibility</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical support</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team appointed to coordinate road safety</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multidisciplinary skills available in team</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well qualified director of team</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial support</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate resources (eg funds, vehicles, equipment etc) available for team to function effectively</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>True cost of road accidents known</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local requirements are considered on a regular basis and acted upon</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local district meetings have road safety on their agenda</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road safety improvements are requested by the local councils</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local requests and problems are considered</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local partnership with businesses and NGOs</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 1.2 Summary of Road safety Management and Coordination

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road Safety Management and Co-ordination (Total)</strong></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-ordinating committees and lead agencies</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road safety strategy/plan</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political support National &amp; City</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical support</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial support</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local requirements are considered on a regular basis and acted upon</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 1.3 Crash Data Collection

<table>
<thead>
<tr>
<th>Desired Conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Data Collection</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accurate Police data collected</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All accident reported &amp; recorded</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standardised data collection from in use with pre-coded data and clear definitions</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Police trained in how to complete and check form</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All important data items being collected on form</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data forms Checked for accuracy/completeness before dispatch to HQ</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forms systematically checked/recorded at HQ to ensure forms returned for every accident reported</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident location being uniquely identified</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate accident location system in use</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All reported accidents capable of being located accurately on road maps</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital data collected</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data forms for injury surveillance system in use</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 1.4 Accident Data Storage and Retrieval

<table>
<thead>
<tr>
<th>Desired Conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident Data Storage and Retrieval</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident data storage and retrieval system</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate accident data storage system</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate checks to ensure accuracy and completeness of data</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adequate procedures and coding system developed to permit easy storage</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System permits easy retrieval of records</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1.5 Crash and Injury data analysis and dissemination

<table>
<thead>
<tr>
<th>Desired Conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash and Injury analysis and dissemination</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Data analysis Police and Health</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>System accessible, flexible and user friendly for analysis</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>System permits scale and nature of problem to be assessed</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>System permits road user groups at risk to be identified</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>System permits trends and characteristics of accident to be analysed</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>System permits black-spot location to be identified and remedial measures to be derived and monitored</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Useful links with other systems</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Dissemination (Police, Health)</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Annual report produced analysing accident trends and characteristics</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Report widely disseminated to key agencies and individuals</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>All key parties aware of the scale, nature of the road safety problem</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 1.6 Summary score for Accident Data System

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident Data system</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Crash Data Collection</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Accident Storage and Retrieval</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Crash and Injury analysis and dissemination</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>
Table 1.7 Insurance and accident costing performance

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Insurance (total)</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All motorists insured</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At least compulsory 3\textsuperscript{rd} party motor insurance required</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All motorist insured</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential rates based on risks, convictions and accident history</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High risk groups pay more than low risk groups</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rates based on vehicle type, driver experience</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.8 Insurance and accident costing performance

| Accident Costing (total)                                                      | 100           |       |                     |
| True cost of road crashes known                                               | 70            |       |                     |
| Realistic cost estimates known                                                | 50            |       |                     |
| Key decision makers aware of costs                                            | 20            |       |                     |
| Accident costs researched and periodically updated                            | 30            |       |                     |
| Research being undertaken                                                      | 15            |       |                     |
| Periodic updating of estimates occurring                                       | 15            |       |                     |

Table 1.9 Summary of Insurance and accident costing

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insurance and accident costing (total)</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Insurance (total)</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident Costing (total)</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1.10 Summary of Road safety Management & Coordination

<table>
<thead>
<tr>
<th>Desired conditions</th>
<th>Maximum score</th>
<th>Score</th>
<th>Percentage awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road safety Coordination</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Safety Management and Coordination (Total)</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident Data system</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance and accident costing</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ABSTRACT
The first part of the presentation gives a detailed overview of the Hungarian road safety situation. Not only the national data and time series will be analysed, but international comparisons will be made, too; and what is more, some road safety performance indicators will be applied in order to reveal the most important problems and trends. After a long deteriorating trend in the number of personal injury accidents and their victims, in 2008 a real „breakthrough” took place in Hungary: for the first time in the latest history of national road traffic, the number of road accident fatalities was below 1000. It is very instructive to highlight the „package” of consistent and co-ordinated road safety measures introduced in 2008 to allow the drawing of conclusions on their effect on road safety situation.

The second part of the presentation will report on the main goal, areas and some details of the latest 3-year road safety action program.

1. ROAD SAFETY SITUATION IN HUNGARY
1.1 National data
After a long deteriorating trend in the number of personal injury accidents and their victims, in 2008 a real “breakthrough” took place in Hungary: for the first time in the latest history of national road traffic, the number of road accident fatalities was below 1000. It can be seen clearly in the Figure 1, where the numbers of motor vehicles and those of personal injury accidents and fatalities are illustrated.

![Figure 1: Number of motor vehicles, personal injury accidents and fatalities in Hungary between 1976 and 2008.](image-url)
1.2 The most important changes in legislation
The number of automatic speed cameras is continuously increasing in Hungary. The most important legal prerequisite of their application was the introduction of the owner’s responsibility (Holló, Weidinger: 2009.1.). It means that the owner of the vehicle is responsible for the offences committed by the vehicle. This rule was introduced as of 1 January 2008, but it entered into force as of 1 May 2008.

As of 20 January 2008, the so-called “zero tolerance” against drinking and driving entered into force. It means that the driving license shall be withdrawn on the spot if one drives under the influence of alcohol (even in case of a small amount of it). This measure was the reapplication of an earlier successful but abandoned practice.

It is very probable that due to this measure, the number of personal injury accidents caused under the influence of alcohol decreased by 18% in 2008 in comparison with the previous year.

The point demerit system has been further developed. As of 1 January 2008, the system became stricter, which means that the number of demerit points increased in a differentiated way. So, the relationship between the severity of offences and the sanctions became closer.

From 1 August 2009 some sanctions became stricter (Holló, Weidinger: 2009.2.). Penalties for non-wearing of safety belt, non-usage of child restraint systems and for usage of the hand-held mobile phone while driving have been significantly increased. For example, the penalty for using hand-held mobile phone while driving is 10,000.- HUF (approx. 40 Euro) inside built-up areas, 15,000.- HUF outside built-up areas (approx. 60 Euro) and 20,000.- HUF (approx. 80 Euro) on motorways. The penalties for non-usage of child restraint system (CRS) are 15,000 HUF/30,000.- HUF/45,000.- HUF, for non-usage of the safety belt or the crash helmet: 10,000.-/20,000.-/30,000.- HUF depending on road categories.

This change could be effective from the point of view of road safety, but it could be problematic too, as higher penalties will be imposed without application of the point demerit system. Here we need further research regarding the efficiency of this change in legislation.

1.3 Some performance indicators
The Figure 2 shows the development of safety belt wearing rates in Hungary (Véssey, 2009).

![Safety belt wearing rates in Hungary](image_url)

Figure 2: Safety belt wearing rates in Hungary

Hungary has reliable performance indicators on the rate of safety belts’ and daytime running lights’ (DRL) users. Time series of these indicators are available from 1992 or 1993,
respectively. The trend in safety belt wearing shows almost the same changes on all road types and seat positions: declining rate from 1993 to 1999 and increasing rate from 2000 on until now (Holló, 2009). This positive development confirms that the road safety policy is on the right track regarding safety belt wearing. The increasing rates are the results of the further development of the point demerit system (at least by 1 August 2009), the co-ordinated awareness campaigns, the more intensive police enforcement and more serious consequences of non-wearing. In spite of positive development in recent years, there is a relatively great potential in the further increasing of the safety belt wearing rates. According to estimations based on the results of meta-analysis (Elvik; Vaa; 2004) additional:

108 fatalities,
369 serious injuries, and
478 slight injuries

could have been prevented in case of 95% safety belt wearing rates in Hungary (Holló, 2009). The usage of CRS shows also a great development, the rate of unprotected children decreased from 65% (1994) to 28% (2009), though on the other hand it means, that almost one third of the children travel still unprotected. The rate of DRL users shows a continuously increasing trend in Hungary (Figure 3).

Figure 3: DRL usage rates in Hungary according to road categories.

1.4 International comparison
The number of road fatalities decreased in the 27 EU member countries by 28% between 2001 and 2008 (from 54,000 to 39,000). In Hungary the amount of the decrease is only 20% (from 1,239 to 996), but mainly due to the efforts made in 2008.

In the Figure 4 the change in the number of road fatalities between 2001 and 2008 can be compared.
If we investigate the short-term change (2007-2008) in the number of road fatalities, we can observe that Hungary was really successful in the field of road safety in the recent years (IRTAD, 2009).

2. THE ROAD SAFETY ACTION PROGRAM FOR 2008-2010
The Road Safety Action Program for 2008-2010 is a three-year project for road safety improvement. On the basis of the Action Program a yearly action plan has to be elaborated for the content and the schedule of the road safety work of the respective year. The program has been prepared in accordance with relevant community directives and strategic documents, as well as with national concepts and sector strategies approved or under implementation.
The Commission of the European Union in its White Paper on European Transport Policy sets the target that the number of road accident fatalities is necessary to fall by 50% by 2010 as compared to 2001. Taking into account the Hungarian circumstances, the objective of the Hungarian Transport Policy for 2003-2015 is more modest, but at the same time it is more realistic: by 2010, the number of accidents with personal injuries and that of accident fatalities of the year 2001 shall be reduced by 30% and at least by 30%, respectively. Whereas the same figures by 2015 shall be mitigated by 50%, in compliance with the requirement of the EU White Paper. The strategy drawn up in the Action Program has also set the target laid down in the Hungarian Transport Policy.

Figure 6: The elaboration of the Road Safety Action Program 2008-2010

This objective is the initial condition of Hungary’s road safety program determining its basic tasks. In 2007, Government Decision No. 2261/2007 (XII. 29.) was entailed on public duties relating to road safety improvement. Accordingly, relevant strategic trends for 2008-2010 needed to be laid down in the form of an action program. Government Decision No. 409/2007 (XII. 29.) provides for the financial resources required for the implementation of certain road safety tasks of the state as well as for the methods of utilization. The ministers responsible for the Ministry of Transport, Telecommunication and Energy (KHEM) and IRI are authorized to exploit the resource.

By Governmental Resolution No. 2261/2007. (XII. 29.) the National Road Safety Program accepted in 1993 and being in force as a framework of the road safety activity lost its mandate. The Government charged the Minister of transport, telecommunication and energy with the co-ordination of public duties relating to road safety.

Basically, it is the unanimous opinion of professional circles that a single ministry is unable to treat the comprehensive problems of road safety; for the purpose of effective measures the co-ordinated collaboration of ministries and professional fields is indispensably necessary. Significant and constant reduction of the number of road traffic accidents and victims is only possible if there is a political will, and the high-level decision makers also accept the necessity to improve the situation of road safety.
In addition, the need arises for the following: analyses of the state of affairs, skilled experts, appropriate work-plans, well considered strategy, professional evaluation of interventions, independent steering/coordinating organisation and last but not least fair-sized funds available for road safety purposes.

2.1 Present situation
Road safety enjoys priority in the European Union since the turn of the millennium. As a result of large-scale measures related to highest political bodies of the community, between 2001 and 2008 the number of road accident fatalities dropped by about 28%. However, this rate is not enough yet for the achievement of community targets. There are significant discrepancies among the member states, because the road safety situation in the Central and Eastern European (CEE) countries is more unfavourable than the tendencies perceivable in the older members. Of course, it’s no wonder, since on the one hand their level of motorization is lower, and on the other hand they were confronted with the problem of road safety later.

In our country, the number of road traffic accidents and that of persons killed during the past 30 years, presents a diversified picture; at the same time certain trends can be demonstrated explicitly. After the successes of the nineties, subsequent to millennium, as a whole, road safety situation took an unfavourable turn, however in 2007 this negative tendency changed.

During the year 2007, the government developed the institutional system of road safety by the establishment of an inter-ministerial committee of specialised under-secretary of state level. In the field of measures dedicated to the improvement of the road safety situation, there was no comprehensive collaboration until now among competent governmental and non-governmental organisations. Today the Inter-ministerial Committee is competent to call this collaboration into existence.

2.2 Presentation of the so-called “pillars”
In the course of actions addressed to road safety improvement, on the basis of situation analysis and international experience, this strategic document has been elaborated according to well-defined development strategy, using the so-called „pillars“.
A great majority of road traffic accidents has to do with the human factor. In addition to general enforcement of traffic rules, in order to moderate the occurrence of certain outstanding risk factors – i.e. inappropriate speed, non-usage of safety belts, driving under the influence of alcohol or drugs – and to improve the safety of vulnerable road users, there is a requirement for appropriate revision of regulations, enhancement of controls, as well as for permanent and effective improvement of road users’ awareness as a result of which the positive change in their traffic behaviour can be achieved.

When speaking about road traffic and its related safety questions, one has to mention the problem of the infrastructure as well: the carriageway and its environment, as well as the vehicles and the traffic characteristics. These factors both in themselves and in their interaction have a road safety impact. In Hungary, the bearing capacity of the pavement structure is largely appropriate; however, it has to be improved for traffic safety reasons, too. The number of accident fatalities on public roads must be decreased by elimination of the high risk sites (so-called „black spots”), or by implementation of an infrastructure with „forgiving” road environment. However, the surplus in traffic volume due to continuous increase of the level of motorization enhances the probability of road accidents’ occurrence.

Legislation is the basis of all measures and the government’s main tool to address the situation. Legislation in road transport needs revision. This means: its simplification, development of a transparent structure for road users, elimination of internal and mutual contradictions and annulment of outdated rules, as well as making regular deregulation possible and compulsory. In the process of regulation, the development of the new system of road traffic rules and the reform of drivers’ education should be given priority. Regulation relating to shaping of the traffic order is also necessary to revise, and if appropriate, it shall be simplified and updated. Financial regulation according to demands of the safety-related activities would also be necessary, allocating the necessary resources to the implementation of actions and measures. Appropriate utilization of the available resources is required to be facilitated by the alteration of regulation. In order to enhance safety, regulation is also needed in some other areas: i.e. the system of regulations concerning the visibility conditions of road users, admitting that some public information has been transmitted in this issue, nevertheless the means of legislation could be even more efficient.

Using the means of enforcement, some accident causes, which can be related to human factors or to some technical reasons, can be prevented more efficiently. Besides the enforcement of general traffic rules, the number of fatal road traffic accidents can be reduced further under the effect of systematic controls dedicated outstandingly to the measuring of speed, to safety belt use, to the identification of drivers under the influence of alcohol or drugs, as well as to the enhancement of the safety of vulnerable road users or as a result of the deterrent effect of harmonized control actions of emphasized intensity.

When control methods are selected, the best European practices (best practices) and new technical achievements shall be taken into consideration.

Support provided to accident prevention activities needs also a change. Improvement of the method of accident data collection which could promote a more detailed exploration of the causes of road accidents, and a better understanding of the circumstances leading to them, is important from the aspect of basic data underlying the road safety related decisions, and for continuous enlargement of professional knowledge. Evaluation of previous programs, which have been prepared and introduced in the same subject, and the knowledge of those programs, which already proved successful abroad also facilitate increasing the efficiency of further design work. During the implementation of the Road Safety Action Program it is also necessary to create the new direction system of accident prevention.
3. CONCLUSIONS
In Hungary a new Road Safety Action Program has been elaborated for the years 2008-2010. A lot of legislative changes were introduced in 2008 and as a result of these a real “breakthrough” took place in Hungary: the number of road fatalities decreased by more than 19% within one year. Just some decades ago, the number of road fatalities was under 1000 in Hungary. Although maybe the improvement is too late in order to reach the quantitative goal of the EU, the results are promising and give a solid basis for further steps.

REFERENCES
Holló, P.; Weidinger, G. (2009.1.) IRTAD, Hungarian statement
   http://internationaltransportforum.org/irtad
Holló, P.; Weidinger, G. (2009.2.). IRTAD, Hungarian statement,
   http://internationaltransportforum.org/irtad
Contents session 2  Preventive safety measures, audits, safety inspections

Collection of Road and Roadside Data to Help Address road Safety Risk
*Blair Turner, ARRB Group, Australia*

Outcomes from a Large Scale Road Safety Audit of the Existing Dubai Road Network
*John Hughes, ARRB Group, Australia*

Recommendations for the Adjustment of Existing Rural roads Towards Self Explaining Roads
*Thomas Richter, Technische Universität Berlin, department road planning and operation, Germany*

Narratives and Accidents
*Beate Elvebakk, Institute of Transport Economics, Norway*

Perception of Unsafe Behaviour of Road Users
*Pr. H. Boudrifa, Laboratory of Prevention and Ergonomics; The University of Algiers, Algeria*
Collection of road and roadside data to help address road safety risk

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Abstract
Road and roadside data has been collected for a number of years in order to inform asset managers. More recently, this information has been put to use to help identify and address locations with high crash risk. This paper provides information on why this ‘risk assessment’ approach has gained in popularity in the last few years. Australian examples are provided of how data is currently being collected in order to assist in managing safety on roads, including recent trials to collect roadside hazard data. Finally, the paper discusses additional uses for this data, including the combination of road and roadside data with crash location data to better inform road safety improvement programs.

Introduction
In the field of road safety engineering, the traditional approach to reducing crashes has been to use crash history as the basis for assessing risk and selecting sites to treat. This approach has been highly successful in Australia and elsewhere (e.g. benefit-cost ratios of 14:1 from the federally funded black spot program - BTE 2001). However, recently there has been a move towards an additional risk assessment approach based on the risk inherent in road and roadside features. This approach has grown from the safety audit process (particularly audits of existing roads or ‘safety inspections’) and has occurred for a number of reasons as outlined in the following section. This paper provides examples of how this data is being collected in the Australian context, and recent developments in the collection and analysis of this data.

Why do we need to collect road and roadside data?
The movement to the collection and use of road and roadside data for safety purposes has occurred for a number of reasons. Firstly, Australia has adopted the ‘Safe System’ approach (see e.g. Turner & Cairney, 2010) which includes the need to address all locations where fatal or serious crashes may occur, not just those where crashes have previously occurred. Given the aims of the Safe System philosophy, it is important that Australian road owners adopt a comprehensive range of strategies to identify and treat crash risks on their roads. Given the relatively infrequent and often ‘random’ nature of crashes over a road network, many locations may exist that have previously had no crash history, or only a small number of crashes. Under a Safe System approach, all locations need to be assessed to determine their potential for fatal or serious crash outcomes, regardless of this history.

Secondly, (and related to this) there are decreasing treatable crash black spots, especially in rural areas, and on other lower volume roads. As an example, investigation of data from one state in Australia and New Zealand crash data shows that only a third of fatal crashes occur in locations classed as black spots. New Zealand data also reveal that more than half of fatal crashes occurred at locations where no other crashes had
occurred in the previous five years. If remedial action is focused only on black spots, the opportunity to prevent a large proportion of crashes will be missed.

Thirdly, there are legal liability issues in Australia in relation to addressing road safety risks with a need for road authorities to know where risks lie on their roads.

Finally, based on research over the last few decades, far more is now known about the road elements that influence the level of risk, and this information is able to be used to estimate which sites are likely to be of higher risk (see e.g. McLean et al., 2010).

Through the use of crash risk research, a number of risk management tools have been developed in recent years. Road Safety Risk Manager, produced by ARRB Group, uses risk reduction figures to aid road owners in prioritising their remedial works in order of potential crash risk reduction per dollar of expenditure (McInerney et al. 2004).

NetRisk, produced by ARRB Group and the Queensland Roads Alliance, uses similar research to identify high risk road sections that may require treatment (McInerney and Doyle, 2006). NetRisk is a process that enables road engineers to scan through a road network relatively quickly and identify the road sections that are likely to pose the highest crash risk to road users. It involves conducting a survey (either while driving or from video footage) of each road length, while paying attention to a certain set of safety parameters (such as lane width, curve radius or roadside hazard conditions). When any important parameters fall below a set threshold, the section of road affected is assessed by filling in a simple form which allocates risk figures based on prior research about these road and roadside features. After a number of road sections have been assessed they can be ranked to identify the areas most in need of attention. Treatments can then be designed and funding allocated depending on other factors such as exposure and the cost of works.

In New Zealand the Road Infrastructure Safety Assessment (RISA) process is somewhat similar to NetRisk, using its own inspection regime to locate areas of engineering related risk (Appleton et al. 2005).

The AusRAP process (which stemmed from EuroRAP) uses crash records to create ‘risk maps’ of Australia’s roads, based on crash rates. The process also uses engineering-based crash risk assessments to allocate star ratings to Australian highways, based on their level of safety from the point of view of an individual driver (Daly et al. 2006).

All of these tools aid road practitioners in locating high risk road sections and devising and prioritising treatments for them.

Australia is currently reassessing these and other risk assessment tools, including any validation studies of their predictive power, to help inform the development of a nationally accepted risk assessment model. This project, funded by Austroads (the association of state and territory road authorities in Australia and New Zealand) is expected to produce a revised risk model midway through 2010.

However, in order to accurately estimate the level of risk on the road network, there is a need to collect a wide variety of information. This includes elements such as road
surface condition, horizontal alignment, lane and shoulder width, delineation and a
variety of other measures.

Accurate collection of this information can be a time consuming task, and one that often
involves subjective assessment. Methods include driving the network and visually
inspecting the road features, or videoing the network for later office-based visual
assessment. Collection of road and roadside information has traditionally been the
domain of asset managers, with little attention applied to the collection of information
specifically for road safety purposes.

With recent technology it may be possible to automate much of the data collection and
processing required for road safety purposes. It may even be possible in the near future
to automatically collect enough data to provide a reasonable picture of safety of the
network. This would dramatically reduce the resources required to assess network
safety, and increase the accuracy of the assessments that are made.

However, at present it appears that in most cases the collection and processing of safety
related data is completed manually. Whilst the video images can be used to objectively
measure parameters (e.g. measure widths with calibrated video images), this project
attempted to identify possibilities for the automatic collection and processing of road
and roadside information (i.e. processing without manual involvement).

What information do we need to collect?

Earlier research conducted by ARRB on behalf of Austroads has identified the road and
roadside features which contribute significantly to road safety risk (see Turner & Tziotis
2006; McLean et al., 2010). These features include:

- horizontal alignment
- vertical alignment
- superelevation
- speed environment (e.g. the desired speed of the 85th percentile driver)
- lane and shoulder width
- clear zone width
- road surface condition (e.g. skid resistance)
- separation of opposing traffic flow
- delineation
- overtaking opportunities/facilities
- street lighting
- access points
- sight distance.
What information can we currently collect?

Equipment already exists to accurately collect data on a number of these features (see e.g. ARRB 2009) including:

- horizontal alignment
- vertical alignment
- superelevation
- speed environment
- road surface condition.

The accuracy of this information in most cases appears adequate for an assessment of road safety risk. New technologies are currently being developed for other road features, but are not yet advanced enough for commercial application.

Features for which there appears to be no ability to automatically process data are as follows:

- lane and shoulder width
- width of clear zone
- type of object within clear zone
- whether opposing traffic flows are separated
- delineation devices present
- overtaking opportunities/facilities
- presence of street lighting
- access points
- sight distance.

Based on an assessment of each feature’s importance to road safety, and the ease with which new technology could be developed, it was recommended that technology to assess the width of clear zones be developed as a high priority.

Development of clear zone detection technology

A trial was undertaken to assess whether technology existed to allow the detection of roadside objects, and the distance to that object. A digital scanning laser manufactured by SICK (the LMS 221-S16), was selected for the trial. The scanner scans at 180 degrees by deflecting an internally rotating mirror. A light impulse is emitted every 1 degree for the whole 180 degrees. The scanning rate of the laser is 75 Hz (75 scans per second) and has a typical range of 30 metres.

Three trials were conducted to test whether this equipment could be used to detect roadside objects. The first trial took place on an urban stretch of road 100 metres long. The roadway contained several trees, a parked car and a number of driveways. Test runs were undertaken travelling at 60 km/h and 30 km/h with the scanner in various configurations. Operating at the same time, a video camera recorded the roadside as the vehicle drove the test route. The scanner was mounted onto a beam on the tow bar of
one of the ARRB data collection vehicles at an angle of 30 degrees to the horizontal and 0.5 metres off the ground.

A typical 60 km/h trial on the 100 metre long section resulted in approximately 85,000 data points being recorded. The format of recording allowed the data points to be easily transferred into Microsoft Excel. This allowed plotting of the distances to objects against the route length.

As expected, not all of the data can be used. Given the scanner was placed at a 30 degree angle, some of the laser beams will be infinitely long as they will be pointing at the sky. Similarly, given a 180 degree sweep is taken, the laser will also emit beams onto the ground almost directly below the scanner.

Initially it was decided to look at just one laser beam to get an idea of the scanner’s output; the beam emitted at 90 degrees. The plot of the 90 degree beam is shown in Figure 1.

![Figure 1: Results from trial 1 – distance to roadside objects](image)

This shows the scanner detecting a number of objects. The next step was to look at the video camera footage to determine how well the location of the objects detected by the scanner correlated with the video footage and to then determine what the objects actually were. The video footage showed the scanner had detected 5 driveways, 13 trees and a car parked on the side of the road. The location of these objects as detected by the scanner, in terms of their position along the roadway, was verified based on a review of the camera footage. The footage showed that the scanner had picked up objects in the correct position along the roadway with a relatively accurate measurement of distance to that object.
Along with the raw data output, the data could also be interpreted to show a 3-D image of the road environment, as shown in Figure 2.

![3-D rendition of test route](image)

**Figure 2: 3-D rendition of test route**

A second trial was conducted in a rural environment, and an assessment made to determine the accuracy of the data that was collected. The route (approximately 2 kilometres in length) consisted of typical semi-rural type terrain (trees, dense scrub, occasional driveways and fenced paddocks). Along with the sensor, a camera was again used to record the roadside, however, in this trial the camera was calibrated to allow manual measurement of the distance to objects (essentially through the counting of pixels).

Spot checks were undertaken to compare the results of the scanning laser to the calibrated camera. In all cases the distance measured by the scanning laser equalled that measured using the calibrated measuring tool.

Main Roads Western Australia (the road authority for the western portion of Australia) sponsored an extended trial of the side scanning laser system with the goal of investigating to what extent this system might be utilised to detect roadside objects and their offset in rural midblock sections. Approximately 150km of rural road distributed across three different roads was surveyed.

Inspection of the associated video images collected during the survey allowed the responsivity of the laser output to be tested. In general, the side scanning laser system was found to be an accurate and viable method for measuring the offset to roadside objects.
It was found that barriers and large trees produced a distinctive signature, which may prove useful if the system is to be used as a tool for screening road sections for further investigation.

There was typically a good correspondence between the offset as measured by the laser and the rated offset based on inspection of the video data. However, while from a safety rating perspective the offset as rated from the video data needs to ignore frangible objects such as light bush and flimsy fences, the laser produced a signature for these objects that is indistinguishable from a non frangible object.

In addition, objects at ground level, such as culverts and drains, are not currently detected by the laser. These are of interest from a safety perspective and are easily detected and their offset rated from the video data. There is however the possibility of reorienting the laser so that it scans at, or slightly above ground level. This would allow the detection of culverts and drains.

The laser also produced what appears to be an exaggerated estimate of the offset of several embankments and cuttings. It is assumed that this is because the laser is measuring the offset height above ground level and hence obtaining a greater offset to the backward sloping surface of the embankment. It should be noted that it is also difficult to measure the offset within the video display when rating offset visually as a result of sloping ground adjacent to the embankments and the curvilinear geometry of the road section in this particular case.

It was concluded that the side scanning laser produces an accurate measure of the offset of roadside objects in rural midblock situations and over the kind of distances required to be of practical use and interest to road authorities. While the system in its basic form does not distinguish between frangible and non frangible objects there is considerable potential to develop filtering and analysis tools to help interpret the nature of the roadside objects detected.

It should be possible to generate a map of a road network, and to highlight on this all locations where roadside objects exist. These tools would allow filtering so that the threshold at which objects are included can be changed (e.g. showing only objects within 5 m, or 9 m of the vehicle).

Combined with other objective road based data (such as horizontal alignment, speed environment and road surface conditions) it is now possible to make predictions about the probability of a crash occurring and the consequences of this in terms of severity. This would allow cost effective targeting of resources to address high risk locations.

**Additional uses for road and roadside data**

The data collected through such processes and through more traditional video observation by trained raters is being used for a number of purposes in Australia at present. Along with providing input to risk assessment tools (such as AusRAP), the data is being used to calculate risk for specific crash types (e.g. for run-off-road crashes) and to help plan appropriate treatment programs for these crashes. The data on road infrastructure can also be over-laid with crash data. This is a powerful tool to determine
what safety features are already present along routes or in areas, and therefore, what treatments are missing, and might form the basis of a mass action program. As an example, run-off-road crashes can be plotted against locations where audio-tactile edgeline has been installed. This quickly shows high risk locations where further installation of such treatments (as part of a mass action program) might prove useful.

**Concluding comments**

Collecting information on the road and roadside is becoming increasingly important for assessments of road safety risk. Currently, collection of information on key risk factors can be a time consuming task and contain some degree of subjective assessment. Collection of data in an automatic way would improve the rate of data collection and the degree of accuracy.

It is already possible to collect some of this information in an automated way. However, for many features no adequate technology existed. In terms of highest priority, information on the distance to the nearest roadside object, and the type of object were thought to be most important. Trials have shown that it should be possible to at least identify the distance to roadside objects. However, it is recommended that further work be conducted to improve this data collection technology, including analysis tools to assist in the interpretation of these data (e.g. a map based tool).

Further automatic data collection techniques are also required, much of this involving some form of object recognition. This would include the ability to recognise roadside signs, as well as road markings (particularly edge and centrelines). Further investment is required to develop this technology, and this may be costly. However, it is likely that the information will be of use not only to safety practitioners, but also to asset managers, so it is likely that the benefits of such a system would outweigh the costs.

Based on the trial highlighted here, it is likely that it will be possible to develop tools which will automatically assess enough factors to determine the risk associated with run-off-road crashes. By combining information on the speed environment, horizontal alignment, road surface condition and distance to roadside objects, it should be possible to identify a relatively accurate level of risk associated with running off the road (along with the expected degree of severity). Such tools would be highly useful in identifying the current level of risk associated with road and roadside features.

Road and roadside data is now also being used alongside crash data in Australia to help in the development of road safety treatment programs, and particularly mass action approaches. There is further potential to use this data in both the assessment and treatment of crash risk, and work continues on these approaches in Australia.

**References**


Turner, B & Cairney, P 2010, Australia’s new approach to road safety: How is the Safe System approach being implemented? *Road Safety on Four Continents Conference, Abu Dhabi*.

Outcomes from a Large Scale Road Safety Audit of the Existing Dubai Road Network

By: John Hughes (ARRB Group), Saad Al Asady (RTA), Richard Jois (ARRB Group) & Brad Lenton (Main Roads Western Australia)

Summary

This paper summarises the outcomes from a large scale road safety audit of the existing Dubai road network. The primary objective of the project was to assess and identify the potential safety risks on the whole of the existing road network and to recommend improvement works or countermeasures to reduce the safety risk to all road users.

The audit has been conducted by a panel of skilled safety specialists in accordance with the Road Safety Audit Manual for Dubai (2008) and also following best practice for road safety auditing from Australia and UK. The extent of the network audited totals approximately 1,906 centreline kilometres or 6,518 lane kilometres.

During the inspection, every single safety finding was described, photographed and well documented. The location of each finding has been recorded using a Global Positioning System (GPS) enabled digital camera which permits a road safety issue to be accurately located, recorded and illustrated in the road safety audit report.

The study identified more than 4,125 potential safety issues distributed across the entire road network. The severity of these risks ranges from “Intolerable”, where the risk is high and urgent remedial action is warranted even if the cost is high, to “Low” where the risk does not constitute major safety hazard but warrants corrective action.

The outcomes of this study showed that, roadside hazards represent the major non-conformance classes on the freeway, expressway and arterials road networks and account for almost 90% of the findings. On collectors and Commercial roads, non-conformance classes such as delineation (Signs, lane marking and chanellisation) and pedestrian safety issues were found dominant and constitute the major parts of the safety risk findings.

Suitable countermeasures to reduce the risk to road users were recommended.

Background

The Roads and Transport Authority (RTA) in Dubai has a vision of “Safe and Smooth Transport for All”. In order to help realise this vision, the RTA commissioned ARRB Group to undertake a road safety audit of the existing major road network in Dubai. The extent of this network totalled approximately 1,906 centreline kilometres or 6,518 lane kilometres.

The primary objective of the project was to assess and identify the potential safety risks on the whole of the existing road network and to recommend improvement works or countermeasures to reduce the safety risk to all road users.

ARRB produced a full audit report covering each road audited, together with recommendations to address the safety issues identified.
The project task generally included auditing all roads within the Dubai network that are defined by the following classifications:

- Freeways
- Expressways
- Arterial Roads
- Collector and Commercial Roads.

This project was initiated by the RTA to assist the organisation towards realising its vision of “Safe and Smooth Transport for All”.

In 2007, 40% of fatality and injury related crashes involved pedestrians and 19% of fatality or injury crashes in Dubai were attributed to hitting a fixed roadside object (1). Reporting on these issues can assist the RTA to prepare suitable countermeasures that target particular hazards on specific roads. Understanding the prevalence of road safety problems can also aid the development of mass action engineering treatment programs which, if applied across whole routes, can have a dramatic impact on road safety.

The main areas for intervention to reduce the frequency and severity of crashes across the Dubai road network were:

- Reduce the number of fixed road side hazards.
- Improve facilities and provide better information (signs) and education on road safety for pedestrians.

The key to success will be creating a forgiving road system, so that when crashes do occur, deaths and injuries can be avoided.

**Project vision**

In addition to identifying road safety issues through conducting a formal road safety audit of all Dubai’s roads, the RTA outlined the following specific objectives to be addressed by completion of this project.

- Minimising the frequency and severity of preventable accidents on the road network, the risk reduction of using the road network by all users.
- An explicit consideration of the safety needs of vulnerable road users e.g. the very young, the elderly, people with a disability and pedestrians, cyclists and riders.
- The likelihood of the number of preventable accidents being reduced.
- The on-going safety improvements to standards and procedures.
- Impact considerations of the ongoing road works and the associated diversion routes.
- Implications of road safety measures as they interface with other parts of the highway network.

**Program for conducting the Road Safety Audits**

The program for the audits was as follows:

Phase 1 – Preliminary phase setting up processes and reporting; was completed in three weeks (21 days).
Phase II – Physical auditing of the Dubai road network; was completed in 26 weeks (182 days).

Phase III – Final reporting; was completed in 4 weeks (28 days).

**Method**

In accordance with best practice, the road network was audited under both day and night-time conditions and in both directions of travel for multilane roads. A work plan was established to identify an efficient travel itinerary to reduce travel cost and auditing time.

The road safety audits were conducted in accordance with the Road Safety Audit Manual for Dubai and best practice from Australia and UK. The audits took the form of a formal day and night time inspection of the road. When on site the audit team looked at the road from the perspective of all road users. This included pedestrians both young and old including disabled access, cyclists, motorcyclists, cars, trucks and buses.

All aspects of the road layout were inspected and safety issues noted in the form of findings and recommendations. The findings locations were recorded using a GPS together with colour photographs linked to GPS for ease of locating each site.

A road safety audit checklist for Existing Roads was completed for each road audited and included in the reporting.

The main report body was automated using an access database developed specifically for this project. The database included the site location and GPS coordinates the date and time and weather conditions at the time of the site inspection. The report took the form of a corrective action report detailing the findings and recommendations and included a risk ranking for each finding.

Supporting documentation and illustrations were prepared from site sketches, digital photographs, and aerial/satellite photographs to assist site identification, treatment type, extent and feasibility cost estimates. All hazards identified by the report were given a risk ranking using the risk matrix below to assess their urgency for remedial action (see risk matrix in Table 1 below).

<table>
<thead>
<tr>
<th>RISK</th>
<th>Suggested Treatment Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerable</td>
<td>The safety concern ‘must’ be corrected at any cost.</td>
</tr>
<tr>
<td>High</td>
<td>The safety concern ‘should’ be corrected (or the risk significantly reduced) even if the cost is high.</td>
</tr>
<tr>
<td>Medium</td>
<td>The safety concern ‘should’ be corrected (or the risk significantly reduced) if the treatment cost is moderate, but not high.</td>
</tr>
<tr>
<td>Low</td>
<td>The safety concern ‘should’ be corrected (or the risk reduced) if a treatment cost is low.</td>
</tr>
</tbody>
</table>
Risk Matrix

The audits took the form of a formal inspection of the road environment. Using the checklist provided in the *Road Safety Audit Manual for Dubai (2)*, hazards have been identified and classified in accordance with the specific non-conformance class as shown in Table 2 below.

**Table 2: Checklist from Dubai Road Safety Audit Manual**

<table>
<thead>
<tr>
<th>Non-Conformance Class</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight Distances</td>
<td>Are all sight distances adequate for the speed of traffic using the road?</td>
</tr>
<tr>
<td>Interchanges</td>
<td>Are the distances between decision-making points sufficient for safety at the operating speed?</td>
</tr>
<tr>
<td>Intersections</td>
<td>Are all traffic signals conspicuous, functioning properly and safely?</td>
</tr>
<tr>
<td>Cross Sections</td>
<td>Are lane widths, shoulder widths and bridge widths, safe for the traffic volume and mix?</td>
</tr>
<tr>
<td>Roadside Hazards</td>
<td>Are all crash barriers correctly and safely installed?</td>
</tr>
<tr>
<td>Drainage</td>
<td>Is the road well drained?</td>
</tr>
<tr>
<td>Signs, line marking and delineation</td>
<td>Are pavement markings satisfactory?</td>
</tr>
<tr>
<td>Pedestrians, bicyclists &amp; motorcyclists</td>
<td>Are all points for pedestrians safe?</td>
</tr>
<tr>
<td>Access to property &amp; development</td>
<td>Are all accesses to/from adjoining properties safe?</td>
</tr>
<tr>
<td>Lighting</td>
<td>Is lighting adequate and safe if required?</td>
</tr>
<tr>
<td>Parking</td>
<td>Is parking safely controlled?</td>
</tr>
<tr>
<td>General road safety considerations</td>
<td>Is the road surface free of gravel and sand and with good skid resistance?</td>
</tr>
</tbody>
</table>

ARRB has produced a comprehensive audit report with findings and recommendations for each road audited to address safety concerns identified by the audits. The purpose of the report was to provide an overview of the project outcomes and a brief summary of the audit findings and recommendations arising from the audits. Recommendations for corrective action were discussed with the RTA to determine whether the recommendations should be implemented, and where it is decided otherwise, to enable RTA to record the reasons in writing for the decision.

**Reporting**

On conclusion of each audit site visit, all the relevant information including the issue (findings and recommendations) location, co-ordinates and photographs were entered into a master database. Additional data such as the auditor details, inspection date, time of day and road conditions were also recorded.
The master database is a permanent record of the audit project and represents one of the largest single road safety audit projects ever undertaken. A screen shot of the master database input screen is shown in Figure 1 below.

![Figure 1: Extract from Master database input screen used in the study](image)

The master database was designed to generate a separate detailed data report for each road audited. Each report presented the findings and recommendations listed in order of risk, as determined by the audit team.

The report also included other important information such as the location of the issue, non-conformance type and indicated which department may be responsible for addressing the issue. An extract from the report is shown in Table 3 below.

### Table 3: Report structure and safety finding information

Non-conformance Report - by Road and Risk Priority

<table>
<thead>
<tr>
<th>Road Number</th>
<th>Road Name</th>
<th>Non-conformance Type</th>
<th>Risk Level</th>
<th>Action Type</th>
<th>Inspection Code</th>
<th>Northing</th>
<th>Easting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Peak</td>
<td>Medium</td>
<td>Road Improv</td>
<td>01-0001</td>
<td></td>
<td>-5000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![An extract from the report is shown above](image)
In addition to the report output, a summary report or Corrective Action Request (CAR) report was produced. The CAR listed each finding and recommendation by road (alphabetical) and risk.

The CAR report included separate columns intended to be used by RTA to record comments regarding the findings and recommendation for each of the issues identified. These may form part of RTA’s formal response to this audit report. An extract of the CAR report is shown Table 4 below.

**Table 4: Corrective Action Request Report**

<table>
<thead>
<tr>
<th>CAR #</th>
<th>Road Name</th>
<th>Non-Conformance Class</th>
<th>Finding</th>
<th>Recommendation</th>
<th>Agree / Disagree</th>
<th>RTA Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2909</td>
<td>Abu Baker Al Siddique Road</td>
<td>Roadside hazards</td>
<td>On a lower speed road the leading support post is greater risk than the non-frangible polar trees in the median. To this distance the rigid barrier may be more of a hazard as it may cause an errant vehicle to launch an impact.</td>
<td>Review the speed limit and remove the rigid barrier on low speed roads.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2971</td>
<td>Abu Baker Al Siddique Road</td>
<td>Pedestrian, bicyclist &amp; motorcyclist</td>
<td>Drop kerbs are not provided to allow connectivity for pedestrians and the footpath on either side of the intersection.</td>
<td>Provide drop kerbs ramp and footpath link for pedestrians.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2972</td>
<td>Abu Baker Al Siddique Road</td>
<td>Sign, line marking &amp; delineation</td>
<td>Pavement edge and line marking on the approach to the intersection are faded and in poor condition. The lack of clear demarcation may lead to an increase in crashes at this location.</td>
<td>Reinstate pavement arrows and line marking on the approach to the intersection.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2974</td>
<td>Abu Baker Al Siddique Road</td>
<td>Sign, line marking &amp; delineation</td>
<td>Pavement edge and line marking on the approach to the traffic signals are faded and in poor condition. The lack of clear demarcation may lead to an increase in crashes at this location.</td>
<td>Reinstate pavement arrows and line marking on the approach to the traffic signals.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Extract from CAR Report**

**Findings**

The primary objective of the project was to assess and identify the potential safety risks on the whole of the existing road network and to recommend improvement works or countermeasures to reduce the safety risk to all road users. The study identified more than 4,125 potential safety issues distributed across the entire road network. The severity of these risks ranges from “Intolerable”, where the risk is high and urgent remedy action is warranted at any cost, to Low where the risk does not constitute major safety hazard but warrants corrective action if the cost is low. The main findings of the safety audit based on road class are as follows:

**Freeways**

Roadside hazards account for almost 90% of the findings on the freeway network. Given the high speed high volume nature of these roads the auditors recommended that it was critical that the number of roadside hazards be addressed to reduce the risk to road users.

**Expressways**

Similarly to freeways, roadside hazards account for over 90% of the findings on the expressway network. Given the high speed high volume nature of these roads, it was critical that the number of roadside hazards be addressed to reduce the risk to road users.
Arterial Roads

While the lower speed environment on Arterial roads reduced the dominance of roadside hazards, the risk of an errant vehicle impact with a roadside hazard remained.

The other non-conformance classes such as delineation (Signs, lane marking and delineation) and pedestrian type issues begin to appear as much more significant issues on arterials than on higher classes of road.

Collector & Commercial Roads

While the lower speeds on Collector and Commercial roads generally reduced the risk to users on these roads, pedestrian issues such as lack of crossing facilities and drop kerbs made up the majority of findings on this class of road.

The table below shows the number and the percentage of non-conformance classes and distributed by severity level. As indicated in Table 5 below, 22 of the non-conformance findings rated as having “Intolerable” severity level are related to pedestrian, bicyclist and motorcyclists. This is mainly due to a general lack of such provisions across the road network, particularly for pedestrians.

The study also found that 3 “Intolerable” non-conformance findings are related to roadside hazards. This is typically due to the incorrect end terminal treatments which were found not to follow current best practice. These end terminals commonly present a sloping barrier end, which if struck by an errant vehicle is likely to cause the vehicle to become airborne or to overturn, inducing a rollover crash with serious, even fatal consequences.

Table 5: Number and percentage of non-conformance classes classified by Risk severity level

<table>
<thead>
<tr>
<th>Non Conformance Class</th>
<th>Intolerable</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight Distances</td>
<td>1</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>14</td>
<td>0.54</td>
</tr>
<tr>
<td>Interchanges</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0.09</td>
</tr>
<tr>
<td>Intersections</td>
<td>2</td>
<td>16</td>
<td>22</td>
<td>0</td>
<td>40</td>
<td>1.87</td>
</tr>
<tr>
<td>Cross Sections</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>10</td>
<td>0.48</td>
</tr>
<tr>
<td>Roadside Hazards</td>
<td>3</td>
<td>205</td>
<td>429</td>
<td>288</td>
<td>300</td>
<td>16.02</td>
</tr>
<tr>
<td>Drainage</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>0.17</td>
</tr>
<tr>
<td>Signs, line marking and delineation</td>
<td>0</td>
<td>10</td>
<td>281</td>
<td>298</td>
<td>586</td>
<td>14.11</td>
</tr>
<tr>
<td>Pedestrians, bicyclists &amp; motorcyclists</td>
<td>37</td>
<td>57</td>
<td>165</td>
<td>165</td>
<td>464</td>
<td>11.73</td>
</tr>
<tr>
<td>Access to property &amp; development</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>36</td>
<td>0.82</td>
</tr>
<tr>
<td>Lighting</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0.44</td>
</tr>
<tr>
<td>Parking</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>2</td>
<td>19</td>
<td>0.77</td>
</tr>
<tr>
<td>General road safety considerations</td>
<td>0</td>
<td>16</td>
<td>14</td>
<td>94</td>
<td>139</td>
<td>2.09</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>635</td>
<td>2525</td>
<td>829</td>
<td>4120</td>
<td>100.00</td>
</tr>
</tbody>
</table>

The above two safety issues present a serious risk to road users across the audited road network and a quick countermeasure should be carried out as soon as possible.
Both pedestrian and roadside hazard related issues rated high in the findings, suggesting there may be a close correlation between hazards and actual casualty rates in Dubai.

The positive aspect of this assumption is that a targeted approach by the RTA to reduce the number of pedestrian and roadside hazard related issues may have had a significant impact on reducing the number of fatality and injury related incidents on Dubai’s road network.

In order to reduce the frequency and severity of crashes across Dubai roads network, it was recommended that RTA consider the following main areas for intervention:

- Reduce the number of fixed roadside hazards.
- Improve facilities and provide better information (signs) and education on road safety for pedestrians

The key to success is creating a forgiving road system, so that when crashes do occur, deaths and injuries can be avoided.

A master work program based on severity level and zone priority has been prepared by ARRB and already put in action by Dubai RTA. The first stage includes implementing the recommended corrective action for the list of “Intolerable” and “High” findings.

RTA estimates that considerable safety risks will be eliminated upon the completion of this stage of the implementation plan. Later stages will be implemented over the next few years and will include all other findings prioritised depending on severity level and cost.

International experience shows that conducting regular periodic safety audits can tremendously improve the level of safety on roads and mitigate the elements of risks to the road users.

It is expected that due to completion of this project and implementation of the recommended safety improvements, the RTA will be better placed to realise its vision of “Safe and Smooth Transport for All”.


References

1. RTA Safety Study, 2007
ABSTRACT
Within the project "safe design of rural roads by normalized road characteristics" (Richter & Zierke 2008) the TU Berlin was researching which road design will affect driving behavior and road safety in a positive way. The project aims are to provide self-explaining and recognizable roads and therefore increase road safety by creating design classes. Based on detailed accident analysis the design classes were derived. The design classes consist of a suitable combination of cross-section and junction designs. Other considerations within the deliberations of safe design classes were the form of operation and the alignment. The evaluation of the roads was carried out by the driving behavior.

The driving behavior was examined in with/without and before/after situations on real roads. The empiric analysis contained over 10,000 km on roads with the following-car technique. Furthermore, the detected self-explaining roads were analyzed in the driving simulator of the TU Berlin. To ascertain the effect of these types of roads they were compared with real roads which were implemented into the driving simulator.

The results of the project show that the driving behavior and therefore the road safety are influenced by the road design. Overall, appropriate combinations of cross-sections and junctions with the alignment in mind affect the driving speed and lane keeping positively. For example the implementation of roundabouts reduced the driving speed on regular two lane rural roads (the design class 3) not only within the sphere of intersections but also in the open road sections. Another major task was the analysis of the influence of a new cross section design for low-volume roads. A before/after study showed that the driving behavior on these roads can be affected positively by implementing the new cross section design; a reduced speed was determined and passing situations with oncoming traffic did not seem to cause problems. Based on these detailed empiric analysis recommendations for planners are given within the project to ensure the correct effects of the adjustments towards self-explaining roads.

1 INTRODUCTION
The standard designs of rural roads vary a lot. The question which road characteristics will lead to a save driving behavior has yet to be answered. So far various studies have conducted research on specific road design elements, but have not been able to give an answer to the questions asked here. One approach to achieve a high quality road network is the standardization of certain road types, which are supposed to have similar road characteristics within their category, but show significant differences towards the other road types (e.g. Riemersma 1986, Theuwes & Godthelp 1995). The self-explaining road can best be displayed by the road marking. Richter & Zierke (Richter & Zierke 2009) determined that the road markings are the elements which are used the most by drivers to classify the road they are driving on. Furthermore the lane separation elements and the lane width have influence on the
classification. Theuwes et al (Theuwes & Godthelp 1995) stated similar elements in their study.

Several studies have examined the effects of the cross section design respectively the road markings on the driving behavior. Some studies were summarized in a meta-analysis of Davidse et al (Davidse et al 2004). The results show that solid lines are recognized earlier by the drivers. Furthermore solid markings provide a higher optical guidance. This leads admittedly to lower drivers’ attention and faster driving speeds. Broken lines provide a lower optical guidance but allow a better estimation of the driving speed. This is caused by the different line-gap-ratio, which conciliates a different driving speed just by using different ratios and length of the markings. Broken edge lines can therefore be used as an “optical” brake for the drivers. Additionally, the driving behavior can be influenced by the width of the marking. Studies analyzed by Davidse et al (Davidse et al 2004) showed that wider markings lead to a lane keeping in higher distances of the marking. A study of Ihs (Ihs 2006) confirms that a centre line on narrow cross sections (6 m) show higher driving speeds than with no centre line. The lowest driving speeds were recognized when the visibility of the edge line is in a poor condition.

In other countries, more effective standardizations of the road classes have already been applied for several years. In particular, the Netherlands and Denmark create a unification of the road system by road classes. Nevertheless, in contrast to Germany the speed-limits of roads are also regulated specifically for each road class within these guidelines (CROW 2004).

In Germany the sectoral design guidelines for rural roads have currently been entirely reworked and, furthermore, combined to new guidelines of rural roads (RAL). Due to the deficiencies of present rules and standards design classes are introduced instead of the velocities which were used previously (V_B, V_e, V_85). In the course of the development of new guidelines for rural roads, the “Richtlinien für die Anlage von Landstraßen (RAL) - Guidelines for the design of rural roads” (FGSV 2008), the aim is to provide self-explaining and recognizable road types for motorists.

Because the RAL only contains the new construction and elementary reconstruction / extension of rural roads it is expected that the design principle will assert itself very slowly in Germany. To fasten the distributional process and strengthen the effect of recognition of the different design classes, the new design principle should also be transferred to the existing rural road network in a contemporary way.

2 THE DESIGN OF SELF EXPLAINING ROADS
According to the new RAL (FGSV 2008) rural roads are classified by traffic relevance into one of four design classes. Thus, the designs of the cross-section and junction as well as the corresponding alignment are playing a decisive role. Expectations are that the general RAL goals of normalizing rural roads will be enhanced by using characteristic designs. This includes a positively influenced driver behavior. In the following the design classes are introduced.

2.1 Design classes in the RAL
Design class 1 has to manage the long distance traffic. It consists of a three to four lane cross section which is designed with a generous alignment to set the suitable speed to about 110 km/h (see figure 1 and figure 3). The connection of roads is processed by grade separated junctions. Agricultural traffic and bikes are not permitted.
Design class 2 consists of a two lane cross section with section wise added passing lanes (about 15 % for each direction is intended). This 2+1 road still allows safe passing without using the lane of the oncoming traffic. Passing in the two lane cross sections is prohibited (see
The alignment is supposed to be semi generous to set the suitable speed to about 100 km/h. The connection of roads is processed by t-junctions with traffic lights. Bikes are not permitted.

Design class 3 consists of a two lane cross section which displays the regular rural road (see figure 2). The alignment is supposed to be semi adapted to set the suitable speed to about 90 km/h. The typical form of junction design is a roundabout.

Design class 4 consists of a new approach of cross section design in Germany. For these low volume roads (daily traffic volume < 3,000 vehicles, truck load < 150) a new single lane road is believed to identify these roads and make them distinguishable to others (see figure 2). The suitable speed is at about 70 km/h.

In summary, the following essential amendments can be ascertained from the comparison of the RAL with the sectoral parts of the previous guidelines:

- new design principle by the introduction of the standardized design classes
- abolition of the speed-oriented design bases
- assignment of intersection types for typical cross sections (in particular the grade separated intersection design of the EKL 1 ensuring an efficient long-distance transport network beneath the autobahn)
- introduction of overtaking lanes as a standard design element for the establishment of safe passing areas (without the need to justify them out of the transport quality)
• operation of intersections with traffic signals (without the need to justify them out of the transport quality)
• introduction of single-lane cross section with central carriageway
• widening of the slightest typical cross section to 6.0 m
• introduction of a traffic related middle stripe
• widening of the shoulders to 0.5 m

3 EMPIRIC ANALYSIS
During the project “Safe design of rural roads by normalized road characteristics” (Richter & Zierke 2008) various road types were analyzed to understand their influence on poor driving behaviour. The suitable road types were preselected based on the current state of the discussion in the task force 2.2.1 of the German Road and Transportation Research Association (FGSV) „Designing new rural roads“, which classifies four different categories. The road types consist of a suitable combination of cross-section and junction designs. Following accident analysis applicable study samples were selected.

For the empirical research test tracks were selected on the basis of a macroscopic accident analysis. For the differentiation of the test tracks the definitions of road types as classified above were used (see 2.1). The sections of road finally chosen were those with the highest achievement of objectives based on the criteria which had been previously defined (Richter & Zierke 2008). The test tracks consisted of at least 5 roads for every design class. Overall a total of 25 roads were analyzed.

Driving behaviour as such cannot be described and must therefore be determined by indicators. For this purpose two different methods were used. On the one hand local measurements were taken at certain locations along the test track. Relevant for the microscopic driving behaviour was data concerning the speed and lane keeping. On the other hand the driving behaviour of a single vehicle was monitored with the following-car technique along the entire test track. In the course of the empirical research radar meters (traffic flow, vehicle class and speed), video cameras equipped for video interpretation (lane keeping) and a test vehicle for the following-car technique (speed, acceleration and lane keeping) of the Department for Road Planning and Road Operating of the TU Berlin were available. Furthermore, the detected self-explaining roads were analyzed in the driving simulator of the TU Berlin. To ascertain the effect of these types of roads they were compared with real roads implemented into the driving simulator. The analysis of the empirical research was carried out using the aggregated data from speed, acceleration and lane keeping profiles. Furthermore, the raw data were analysed statistically to verify the reliability of the conclusions or at least deduce observable trends. Earlier studies have shown that a sample size of 100 vehicles in free flowing traffic for the stationary measurements and 20 to 30 trips in each direction are sufficient. The comparison with the results from the stationary measurements showed satisfactory representativeness.

As a basis for the tests in the driving simulator the existing knowledge about the composition of suitable road types was utilized. The defined road types were programmed for the tests in the simulator. They had to be driving behavior optimized and include the requested road characteristics. For comparison five real sections which had been analyzed during the empirical research were integrated into the tests. This allows an evaluation of the driving simulator comparing the real sections driven in the simulator and in situ on the one hand and a comparison between the real sections and the driving behavior optimized sections on the other. A total of eleven different roads were analyzed. These are split up in one real and one driving behavior optimized section for each design class. Additionally, for design class 3 a different junction design (single level junctions and roundabouts) was examined separately. In addition to the parameters described in 2.1 variations of road markings, in
particular in design class 4, were analyzed. Additionally to the measurements taken on the real roads (speed, lane keeping) visual behavior of the test drivers was captured in the driving simulator. Overall 30 participants with three runs on each road design were examined. The results of the tests in the driving simulator were being statistically analyzed in the same way as the results from the in situ measurements to guarantee comparability. Different to the real roads the effect of the presence of other traffic in the simulation was included in the analysis. Overall the speed profiles of the participants in the driving simulator study showed a high consistency.

The empiric analysis was used as a basis to assess the safety levels of different design characteristics.

4 ADJUSTMENT OF EXISTING ROADS

4.1 General strategy
In general, the adjustment of existing roads should not be carried out with the help of an overall consideration in the form of a deficit analysis, but be implemented during conversion / expansion measures caused by other demand inquiries (road safety, flow of traffic, road constructional deficiencies). In the existing road net the adjustment is to be planned in the borders of "net segments" to aim at uniform characteristics for such net segments.

Design elements which appear continuously on roads (e.g. cross sections, markings) must be clearly distinguishable from others which appear selectively (e.g., curves with small radii and large direction changes). Therefore, it has to be indicated how these selectively appearing elements have to be changed reasonably according to the RAL. To be able to carry out the assignment of a section of road to a design class, design class specific measures have to be given (Richter & Zierke 2009).

Essential basis for the creation of recognizable roads are the marking of roads. To make a road recognizable from another class for the users, it requires a distinctive characteristic. The characteristic must be of high traffic related relevance for the road user and constantly be in the user’s range of vision. The longitudinal road marking fulfills both conditions best of all. The characteristic road markings of the four design classes are:

- a traffic related middle stripe for the separation of the directions of traffic, consisting of a double lane boundary line with a green-colored filling, displays a road of the design class 1
- a double lane boundary line for the separation of the directions of traffic or in special cases a double guideline in the middle of the road without colored filling display a road of the design class 2
- a single axis line in the middle of the road or a single lane boundary line with a double-sided 0.25 m wide shoulder display a road of the design class 3
- a single lane cross section without an axis line in middle of the road and a broken line with an offset of the edge display a road of the design class 4

The marking of the design classes by the typical longitudinal road marking must be carried out over a minimum length of a marking segment so that the road user understands these characteristic elements as a differentiation for certain road types. The desired lengths for the markings differ by the design classes.

4.2 Requirements
To be able to carry out the assignment of a section of road to a design class, design class specific measures for each design class are necessary. The measures have to take into account the compatibility of the single elements. In general, some measures are basic requirements for
the adjustment. They must be implemented to enable a marking of a certain design class and, for this reason, guarantee the recognition of a road type. Other measures do not have necessarily to be implemented. They contain the improvement of other design characteristics by which the roads of a certain design class should be approximated to the default of the RAL for reasons of road safety and traffic flow. Nevertheless, the implementation of all elements should be aimed for.

4.3 Measures for the adjustment
In the following possible adjustment measures are presented for each design class. The results are based on accident analysis and the evaluation of the driving behavior (Richter & Zierke 2009) (Richter & Zierke 2008).

Design class 1
For design class 1 the separation of both driving directions and the grade separated junction design are the essential elements (see 2.1). The existing road net often shows road sections within a net segment which is assigned to design class 1 with two lane cross sections and at-grade intersections. In these sections the installation of passing lanes and grade separated intersections are indispensable. The measures for design class 1 are basically justified by the high speed level. For example, the average $V_{85}$ speed on roads of the EKL 1 with a “2+1” cross section was at about 110 km/h. Exemplary one speed profile of a 2+1 road is shown in figure 3. Due to the high speed level at-grade intersections are not appropriate.

![Figure 3: Speed profile of a 2+1 road (design class 1)](image)

Possible measures to achieve the level of a design class 1 road and to implement the characteristic marking (green-colored filling) are:
- Prohibition of bikes
- Installation of passing lanes
- Installation of grade separated junctions
- Elimination or protection of unsteady alignment elements
• Widening the cross section
• Removal of agricultural roads and installation of non-built up areas

Additionally, the designation as a road restricted to motor vehicles (no (agricultural traffic) and the reduction of connections with roads below design class 3 should be aimed for. Due to the high costs of grade separated junctions this will be devoted.

**Design class 2**

Within design class 2 five test tracks with the characteristic design elements were analyzed. Exemplary one road of about 9 km with two junctions with signal control is shown in figure 4. The speed profiles of the open road show that the speed is slightly lower than for the test track of design class 1. To achieve an appropriate speed level within the intersections the length of the area with a speed limit before the intersections should not be undersized. In general, every intersection should be signalized.

Possible measures to achieve the level of a design class 2 road and to implement the characteristic marking (double lane boundary line for the separation of the directions) are:

- Prohibition of bikes
- Installation of passing lanes on at least 15 % for each direction
- Installation of signalized junctions
- Elimination or protection of unsteady alignment elements
- Widening the cross section

![Figure 4: Speed profile of a two lane road with section wise passing lanes](image)

**Design class 3**

Within design class 3 ten test tracks with roundabouts or regular junctions (mainly t-junctions) were analyzed. The speed profiles of the test tracks showed high driving speeds especially on intersection areas (figure 5). This results in the demand to reduce the speed at connections with other roads of design class 3 or lower. This can best be achieved by the implementation of roundabouts. This measure can best be rationalized by the analysis made in the driving behavior. The comparison of the design class 3 roads with the equal design
elements but different intersection design displays that not only the speed in the area of the roundabout is much lower than at the t-junction design, but also the speed level on the open road section is more appropriate for two lane rural roads. If no roundabouts are implemented in the existing roads a speed limit of 70 km/h should be posted in intersection areas.

Possible measures to achieve the level of a design class 3 road and to implement the characteristic marking (double lane boundary line for the separation of the directions) are:

- Conversions of junctions to roundabouts
- Elimination or protection of unsteady alignment elements
- Widening the cross section

Figure 5: Speed profile of a two lane rural road with different junction designs (t-junction and roundabout) in the driving simulator (design class 3)

**Design Class 4**

Within design class 4 seven test tracks with the characteristic design elements were analyzed. One of them was additionally equipped with a new road marking for a before/after study. After repaving the marking of this stretch of road consist of two broken edge lines with an offset of 0.75 m from the edges of the road (2 m length of the line, 2 m space) according to the RAL (FGSV 2008) (see figure 2). The old road marking existed of two solid edge lines which could hardly be seen and a spaced axis line (3 m length of the line, 6 m space). The existing road network shows especially on low volume roads very different design standards which are not indicated by the markings. By creating the new single lane cross-section the low-volume roads are strictly separated from other roads. The implementation of the new road marking for design class 4 is the basic measure to convert these roads into self-explaining roads.

The analysis of the new road marking was carried out in a before / after study. The average speed reduction for all percentile speed profiles three month after the remarking was up to about 10 km/h for one direction. The other direction which already had a lower speed level in the before-situation showed a less noticeable speed reduction. The measurements after a one year period did not confirm these results. The speed went up to the level of the old marking.
Under the circumstances of a new surface these results can still be rated as a positive effect on the speed behavior. The analysis of the speed behavior in the driving simulator of all test subjects (n=45 rounds) without other traffic resulted in the profiles shown in figure 6 and therefore validates the positive effect on the speed behavior. The average speed in the before-situation was about 95.2 km/h. The after-situation had an average speed with a reduction by 5% at about 91.3 km/h. An analysis by section for the open road and the junction area shows that the before-situation had an average speed of 105.0 km/h and 83.4 km/h. For the after-situation with the new single-lane cross-section for the open road section a reduced speed at about 99.9 km/h was noticed. For the junction area the average speed went up to about 86.3 km/h. A precise consideration of the 85% speed shows likewise to the results on the test track a reduced speed in the open road section. Furthermore for the driving simulator section the speed reduction of high speed levels decrease stronger than on lower speed levels. The converse progress can be noticed in junctions. To ascertain the effect of the new road marking on the speed behavior further long term research on real roads should be carried.

![Figure 6: Speed profiles of design class 4 in the driving simulator with the old (before) and the new (after) marking](image)

The lane keeping analysis at a certain station with an even alignment resulted in the expected way. In the before-situation all drivers kept their vehicles totally on their own lane. In both after-situations (3 month/1 year) the vehicles are driving about 0.3 m further to the left. Furthermore the shoulder is not getting used for the free driving. Just in passing situations with oncoming traffic some drivers equivocate on the shoulder. This displays that the wanted effect to keep the drivers further off the edge of the road and therefore lower the risk of accidents where the cars deviate to the right can be achieved by the new marking.
5 SUMMARY

Essential basis for the creation of recognizable roads establishes the marking of roads. Concerning the cross section design it has to be indicated, how the width of the paved surface should be split suitably on to the elements of the cross section, if the carriageway width deviates from the standard measures of the RAL. Besides, the existing road network shows a huge number of different kinds of intersections (intersection basic forms and operation forms) in progress of continuous roads. The purpose of the RAL is to bring certain kinds of intersection to the application with roads of a specific EKL and, thus, to contribute the recognition of the design class. For this standardization recommendations for the adjustment of intersections are essential. Furthermore, recommendations for all aspects of the alignment have to be given whereas in particular the observances of the radius relation as well as the verification of the spatial alignment have to be emphasized on existing roads.

A high importance also comes up to the adaptation of the adjacent road segments. This has to be carried out for reasons of the road safety and the formation of uniform net segments in progress of conversion and expansion measures. For the road user, a safe use of the road should be also guaranteed in the inventory sections with the driving behavior chosen on converted / expanded road sections. This becomes more significant as the speed differences between the rebuilt one and the not rebuilt segment increases.

To clarify the categorization of a design class and to ensure the effect of a self-explaining road design the posted speed limit should be adjusted in the German traffic law as well because different to the Netherlands and Denmark the speed limit can yet not be predefined in the road planning guidelines.

The implementation of the new road marking will take several years. Therefore recommendations have to be given to the planners to ensure the correct effects. To develop the recommendations a task force for the implementation of the design classes has been founded by the FGSV in 2008.

REFERENCES
CROW (2004) Guidelines for the implementation of the characteristic road designs. Ede 2004


Riemersma, J.B.J. (1986). The perception of speed during car driving II, TNO for SWOV Institute for Road Safety research, Soesterberg

Narratives and Accidents
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Introduction
In 2004 the Norwegian Accident Investigation Board was expanded to include a new section for road traffic. Their task, as defined by the Government, was to investigate individual road accidents, in order to find out what had actually taken place, and to construct road safety advice on the basis of their investigations. The overall ambition behind the new organisation was to reduce the number of fatalities in road traffic.

In this paper, I am exploring the idea that the main task the Accident Investigation Board’s section for road traffic was to construct a new kind of narratives about road accidents, and from this perspective, I will discuss what kinds of narratives have been constructed, whether they have been productive, how they interact with various conceptions of causality, and how these narratives have been made to fit into the existing structure of road safety work in Norway. The paper is based on interviews with employees in the road safety department of the AIBN, in the Road Directorate, and in the Ministry of Transportation.

The Official Story
Around the year 2000, Norway had a good track record in road safety\(^1\), but in the Department for Road Safety in the Ministry of Transportation, there was a still a strong commitment, and even a perceived obligation, to further reducing the numbers of fatal and serious accidents. There was, for one thing, a general desire to see the statistics improve from year to year, and certainly not to deteriorate, which was agreed to be the likely result if traffic kept steadily increasing and no new measures were introduced to counteract the impact. Many of the traditional measures could be seen as being exhausted, or at least exhausted within present budgetary constraints, so the question that arose, as one of the informants from the Ministry of Transportation put it, was “What now?”. Could there still be potential benefits out there that one did not know about? Could new ways of looking at accidents bring forth completely new ideas about how to prevent them?

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\(^1\) Norway has typically been among the European countries, along with Sweden, the UK and the Netherlands, with the lowest relative numbers of casualties is road traffic.
The other transport sectors were also seen to be ripe for re-organisation when it came to how accident investigations were carried out; the Norwegian railway had been subjected to several major accidents in the preceding years, and the traditional investigations in the maritime sector were seen to focus too narrowly on legal blame and responsibility, thus not promoting learning in the same way as investigations in air traffic.

In 2001, the then secretary of Transport, Terje Moe Gustavsen, visited the American Accident Investigation Board in Washington, which holds a broad mandate, and investigates road accidents as well as major accidents in general. Based on observations of their work, and also on the background on the prevailing opinion that the existing Norwegian Accident Investigation Board for Air Traffic had been very successful, it was decided to work for a similar solution in Norway. It was believed, on the basis of the American experience, that such a multi-sector organisation could benefit from economy of scale, and that it would also be possible to introduce a more cross-disciplinary approach that would include insights from the social sciences and competence on human factors in addition to the more technical aspects of accidents. The mandate was not, however, an exact copy of the American model; the Norwegian Board was to be limited to the transport sector.

Official publications regularly compared the relative risks of different modes of travel, and it was always striking that flying was by far the safest mode of travelling. The Accident Investigation Boards were seen as crucial contributors to this favourable situation in the sector, and thus it was suggested that an extension of the board to other modes of transport could lead to a significant learning effect between sectors.

Prior to this, however, The Norwegian Public Roads Authority had already started deploying so-called accident analysis groups that write reports on every single accident involving fatalities in order to assemble information on causes of accidents, and the idea was to use this data (individual as well as cumulative) as basis for preventing accidents in the future. Some people did still not find this satisfactory, as the competence of these groups was usually primarily technical. There was also a suspicion that the Public Roads Administration might defer attention away from the shortcomings of the infrastructure, the maintenance and development of which they were themselves responsible for, and the Accident Investigation Board’s independence was thus seen as an additional advantage over these groups.

The expansion of the Board did not meet with any kinds of political opposition, but passed through Parliament on a unanimous vote, and was later followed up by a different government. Among the professional actors, however, a more cautious attitude prevailed. According to the informants from the Norwegian Road Directorate, they were on the whole positive to the expansion of the Board to the road sector, but expected them to possess a competence that contrasted, rather than competed with their own accident investigation groups. Others, however, felt that the Road Directorate was less than enthusiastic about the new organisation,
and that the Directorate, as well as others in the sector felt that this was an area
were the Public Roads Administration would be better off dealing with their own
problems, the way they had done in the past.

The Accident Investigation Board

Though official documents provided a general framework for the activities of new
organisation, their mandate was not described in much detail. There was an
explicit ambition that the organisation ought to benefit from its autonomous
position, and thus there was also considerable manoeuvring room when the
practical day-to-day operations of the Board were to be given shape.

The new section was intended to benefit from its co-location with the other rest of
the AIBN, and also to adopt a methodology similar to those used in air traffic.
Significant differences existed between these sectors, however, that were seen as
possible obstacles to copying the methods of the existing boards. Most
importantly, unlike the air sector, road traffic is characterised by a very high
number of accidents, but most of them are not serious, and do not lead to serious
injury, and even for fatal accidents, the number of fatalities is typically very
limited.

The fact that the number of potential accidents was so high also meant that an
attempt to investigate all accidents and near-accidents, as is the case in air traffic,
would be forbiddingly expensive, especially as the organisation was intended to
have a staff of similar size to the other sectors, that is, 4-5 persons. It was
therefore necessary to find some way of delimiting the task. The official
documents suggested that the Board should focus on accidents with “high
potential risk” (not necessarily catastrophic consequences), and, most importantly,
with a high possibility for safety improvement, through potential for acquiring
new knowledge. It was further assumed that these requirements would probably
lead to a focus on professional traffic, such as public transport and goods traffic,
as it was believed that these accidents could more profitably be investigated with
methods from the air sector, as there was more a similarity between the actors
involved. As in the air sector, it would be possible to relate to an organisational
environment, rather than to individual drivers and their highly individualised
backgrounds and networks. It was thought, in other words, that the Board might
fruitfully build on the existing structures in terms of regulations, such as HES
regulations, thus making the systems perspective inherent in the investigations in
air transport more transferable to the road sector. In other words, it was assumed
that the systems perspective could be more fruitfully applied where there was an
established system in place. However, as one of the informants from the Ministry
pointed out, the systems were still very different from the air sector, as
professional road traffic is characterised by a very high number of professional
actors, and frequently these organisations are very small, indeed many of them are
single-person businesses.

So far, the AIBN has only investigated accidents involving professional actors,
but, as it has turned out, this has not always been sufficient to convince all
relevant parties that the systems that they relate to are the ones that they should 
attend to, and that their recommendations are fruitful.

Unlike police investigations, the AIBN explicitly (and in compliance with 
international regulations of airline investigations) avoids stating only one cause of 
the accident; the ambition is to find how several causes work together, and how 
the process leading to the accident could have been intercepted at different points. 
Their investigations are not to distribute guilt, and the information that is 
uncovered in their interviews cannot be used as basis for criminal procedures.

The reports of the AIBN concludes with safety recommendations, that are indeed 
their main product. These recommendations are based on the results of the 
individuals investigations, and are to point to weaknesses in the system. The 
recommendations are sent to the Ministry of Transportation, who, in their turn, 
hand them over to the Norwegian Public Roads Directorate, who are responsible 
for closing the recommendations. They report back to the Ministry, who also 
inform the AIBN of the progress of the process. The AIBN’s responsibility ends 
with the completion of the report, and they are not to comment on the process of 
closure, as this would be seen to violate their autonomy. This did not, however, 
prevent the employees of the Board from having strong opinions on how their 
recommendations had fared in the system, as we will see.

**New stories about Accidents?**

The stories told by the Norwegian road administration had traditionally been 
stories of aggregated numbers: so many people died last month, and the number of 
casualties has been reduced by 25% since 1980. These numbers could of course 
be quite detailed, as when providing the average age of drivers involved in 
accidents, the average age of the car, the kind of road or the time of day when 
accidents happen, and so on.

The stories thus told also served a very specific purpose; they established causal 
links. The high number of young drivers involved in accidents also serves to 
construct the young driver as the kind of thing that may cause accidents.

With the AIBN, this changed radically, as the focus was now on one single 
accident at the time, and the story of this accident related in painstaking detail.

“Around 8 o’clock in the morning on Thursday September 29th 2005, an 
18 year old girl drove from Trøgstad in the direction of Mysen High 
school, where she was a student in her final year. On her way she went by 
a house in Krogstadfossen, to pick up her 17 year old friend from school”.

This is the beginning of one of the AIBN’s reports. It sets the scene in a way quite 
different from the standard accident statistics that we are usually presented. It 
relates the story of the accident, how it unfolds inexorably towards the point 
where the car is hit by a truck when turning into the state road, and the crash 
leaves the young driver dead, and her passenger severely injured. The report is 
illustrated with maps and photographs from the scene of the accident. It briefly
describes the two drivers; her experience with driving, her driving school education; his daily job and routines, and working conditions on this particular day. From this point, the investigation turns to what the causes were, and how the accident, or its consequences, could have been avoided.

The safety recommendations based on this accident were the following:
- that the Norwegian Public Roads Administration requirements for visibility from existing, and a system to follow up these requirements
- that the Norwegian Public Roads Administration establishes guidelines to ensure that the right of way on crossroads to heavily trafficked roads is made clearer to road users.
- that the Norwegian Public Roads Administrations analyses accidents involving drivers with recent licences in relation to their achievements in driver education and driving tests.

I have discussed some aspects of this particular report with the investigator in charge (ICC) in the AIBN and with the leader of the relevant department of the Roads Directorate, who is in charge of following up the recommendations. This was how the ICC described the reactions that his report had met with:

“[This report] has been laughed at, because they think we have expected more than they should really be responsible for. But I disagree with them, and – of course lots of other things are more important, but it’s such a central finding, that I believe it is important. This is to do with visibility; that you make sure that visibility is such that you can actually drive safely. It’s not according to the books; that’s not it, but what can be carried out safely. And I believe that the road authorities should take on that responsibility and make sure that any driveway into the road network is sufficiently safe. And when the law enables them to take whatever measures necessary to secure this, I think that is in order”.

The point is that from the perspective of the narrative constructed in the report, there is clearly something that could be done in order to prevent this accident: improved visibility and a clearer right of way might actually have made a difference. There is a point where the relevant authorities might have intercepted, and a safety barrier could have been erected. However, this kind of narrative does not sit well with the logic applied in the road directorate, and this was how the same case was presented by my informant there:

“two years ago there was this eighteen years old girl, recent drivers licence, had driven from home and onto the public road, from her own driveway, and was killed because she didn’t look around her. And then they made a recommendation that the Public Roads Administration should control every driveway every year, or at least at regular intervals. And, you know, it was her own driveway, and inattention. If, on the other hand, we were to control every driveway in Norway, that would probably amount to a hundred man years or so a year.”
This creates an entirely different story: the story is first and foremost one about individual blame; a recent licence, she does not pay attention, and it is her own driveway, with which she should be familiar. These are known risk factors, that are already familiar from known road safety statistics, and as such, the story is brought to a satisfactory end: there is, after all, one cause, and that cause can be located in the single, inexperienced and inattentive person. This is a narrative that does, in its own way, have a neat closure. In the manner of a crime novel, and in the manner of the criminal investigation frequently following a road accident, the story is brought to a close when the guilty person has been identified. As another employee of the AIBN put it:

“The police want to distribute blame and responsibility. If you have a single accident and the driver was killed, then it is not interesting, and the case is closed, because the guilty party cannot be found.”

The closure of this kind of story can be quite convenient, because it seems to suggest that there is actually not very much that can be done from a systems perspective, it is the isolated individual that is the cause, and therefore the system is, in a sense, blame-free. Another employee at the Public Roads Directorate was quite explicit that even if you could always “blame the system”, this was not always a fruitful approach to take to accidents:

“causal chains can be traced too far, not every consideration is always equally interesting. But this probably stems from the methodology, which to some degree locks in the AIBN’s work, and sometimes leads the recommendations in too many directions. It gets too complicated, too specific. One has to ask oneself what will contribute to the reduction of the number of casualties and injuries.”

So the notion of causality is not seen in isolation, as a purely factual aspect if the accident; it ties in with the practical day-to-day work of accident reduction. The ICC in charge of the report was also quite aware of this of this problem, and did indeed see the Directorate’s perspective:

“when you have 10 000 road accidents in Norway every year, and some – I don’t know how many – are related to lack of visibility, but I don’t think that’s a lot. And then it is a kind of recommendation where you don’t go “Naturally, we’ll have to do this”. In light of having a lot of accidents, and then you are told to prioritize visibility in driveways, it’s no wonder you laugh at it. But then you miss out on a perspective – you are more concerned with the forest, as such, but not the individual trees, if you see what I mean.”

And the Board, of course, is there to consider the individual trees. It is the story of the individual accident and its possible prevention that it is their task to construct. But in the wider system, the task is not to prevent every single accident; it is to reduce the overall number of accidents as much as possible within the limitations of available resources, and within the framework of established routines and practices. As the leader of the safety department in the directorate saw it:
“the problem is that when [recommendations] become too specific you might have a problem with finances. For problems can be solved in many different ways, and not necessarily in the most expensive way. And you do not always need a 100% effect; you can do well with a 50% effect, to put it a bit simplistically.”

So their stories are not stories about rendering the individual accident impossible, or even improbable. These are stories of a reasonably safe system, where failures may well occur, but not too often. There should be improvement, but perfection is not really on the cards. A cause in this context is not merely a cause, it is a factor to be evaluated within a system of such factors, and when it does not fit in, it will simply be discarded. The cause that survives is the cause that brings the story to a satisfactory conclusion, and this conclusion is also always a practical conclusion. As such, some of the stories that have been constructed by the AIBN have been seen to be lacking, because they do not seem to fit in with the kinds of stories that are told in the system at large. What help is there in spending a fortune on improving visibility, if the work is not reflected in next year’s road safety statistics?

Thus the AIBN were sometimes dissatisfied with how their recommendations were received, and, on the other hand, the Road Directorate felt that recommendations did not fit into their existing systems, or take their practical situation into account, especially where financial resources were at stake:

“They are not financially responsible for their suggestions, and it’s probably right that they are not, but on the other hand they should consider whether the problem is of such a magnitude so as to justify those kinds of investment”.

On the other hand, the AIBN employees did not experience the Directorate as entirely open to new suggestions:

“I also think the process could be improved. I feel that we haven’t got a good enough dialogue with the recipients of the recommendations during the process, and that is also because the recipients aren’t always that susceptible to recommendations. It’s a bit of a hair in the soup, right? They involve extra work, or they usually do. At least you can choose to look at it that way.”

The Road Directorate is an old and heavy organisation, without much experience with having to relate to external pressure, or at least not to external evaluation that probes into their ways of working, and choice of methods. An informant from the Ministry of Transportation had also noticed this problem between the two organisations, and tended to see it also in terms of a conflict of competence, and a certain unwillingness on the part of the Directorate to acknowledge the relevance of the new kinds of narratives produced:

“There was spent relatively much resources on going against, and almost disprove the advice and recommendations that were raised. It is not unusual in rail and air traffic that recommendations are not followed down
to a T, but that it is noted that it is not seen as fruitful to go further along those lines… but there was a lot of fuss and work spent on that. There was - at least that is my impression, a very negative focus. “

What are the characteristics of the new narratives about accidents constructed by the AIBN? The new features seem to fall into several categories. For one thing, the reports, with their natural focus on preventing this single accident, brought with them as sense of urgency; the task is not simply to reduce the overall number of accidents, but to turn every stone in order to prevent this one. It is perhaps an inheritance from the methodology of air traffic, where every accident is potentially catastrophic. In the road system, it seems that there is more of a tradition of accepting “the normal disaster”. As has frequently been pointed out; if all the people dying on the roads had perished in one go, we would have a public outcry, and the Minister responsible would have to go. As it is, however, it seems difficult to convince the actors in the system that an urgent and drastic response is necessary to prevent every single death, The AIBN seeks to close every safety hole, whereas the Road Directorate wants to focus on closing the biggest holes. However, some of the employees in the AIBN suggested that their position was better understood by people working closer to the operative part of the Roads Administration who “felt the problems more acutely”. As individual tragedies, one will assume, rather than as aggregated numbers.

Another difference is that the AIBN’s narratives do not find their natural end-point in the responsible and fallible human actor. As we have seen, it was originally thought that their approach might be best suited to professional traffic as that is where there is a system in place, in other words; that private citizens are better suited to be evaluated in terms of individual guilt and blame. But the idea that the systems approach is best suited to commercial traffic was also challenged by the AIBN. If you construct the kind of narratives that they do, it seems that every actor is part of a network that can be modified, and that is, already, subject to official regulation and modification:

“[…]. you actually have organisations behind every accident. If private citizens are on the road, then there are, we might say, no organisation behind them, but you still have an organisation behind the road system, which we look into. And we also look into, relative to how the systems work, among other things where health information is concerned. How that is taken care of; there are health requirements for driving. The health system, how it works, how it operates relative to licence regulations, and having a licence.”

In this kind of story, the causal chain does not stop with the individual, but can potentially always be traced further. It conjures up the image of a different kind of networked society, where individual actors are not isolated first movers, but
always enmeshed in a system that could have an impact on their actions, and their consequences.

“it’s fine to have guidelines and road standards, and everything, but you also need to know that those standards work. If you built a road in accordance with the standard, and 30-40% of the people using the road use it incorrectly: is there something wrong with the system or with the people using the system?”

Contrast this with this opinion offered by an employee in the Directorate:

“Your average car driver is not a professional, and using a “systems approach” is more fruitful, when you are part of a system, such as employed by a company. In many accidents, the driver is the main cause of the accident, we are talking about explicit mistakes, and if that is the case, recommendations directed at other fields appear odd.”

But these difference also always tie in with the question of how one should relate to the fact that resources for road safety are, after all, limited.

A further difference between the two types of narratives has to do with temporality:

The thematic report – an acceptable story?

The AIBN had also issued one report that, rather than focusing on one accident, treated three different accidents that were all related to the question of driving and road maintenance in winter time. This was perhaps no major departure from their usual methodology, but it did nevertheless seem to suggest one way of giving their narratives a different kind of momentum.

“It’s a challenge, but I wouldn’t say it’s necessarily a different perspective, for what I have in mind is giving the recommendations a new kind of weight. The winter report was based on three accidents, so we’re not talking huge statistical material, and we’re not talking about statistical significance, but to bring to the light different - this can have two sides to it, really – to bring to the light different variations of a problem that can be very interesting, for instance use of seat belts and that kind of safety equipment in the car, where you have many different issues, and where one investigation becomes so limited, one accident”.

So this was seen as a way of giving their recommendations a different kind of weight; it is no longer about the one accident – it is about this problem that is encountered in different settings. It is the safety problem that becomes the thing around which the narrative revolves, not the individual sequence of events, which might appear arbitrary and idiosyncratic. This feeling was echoed by an employee in the Ministry of Transportation:

“I think it seems very good, because they don’t have big samples, so when they make very broad recommendations based on one single accident, then
it is hard to generalize. So I think [thematic reports] render recommendations of a more general character – legitimate might not be the right word – but that they are perhaps more believable, then. Not that they are not today, but they acquire that weight; now they can say it wasn’t just that one accident, we have looked into several.”

So perhaps this is a kind of narrative that can do the work of tying together the two kinds discussed so far – the individual accident is no longer a free-standing incidence, but an instance of a problem. The plot revolves around something that is recognisable as a general issue, something that is not tied to this particular person, on this particular day.

In general, the organisations have made an effort to collaborate more fruitfully over the last year or so. The AIBN have tried to modify their recommendations in such a way as to make each of them more effective, and more acceptable to the receivers:

“We may have become somewhat more pointed, and perhaps we have left out some considerations that we haven’t given so much weight, and made some more considered choices. “We’ll put that problem up front and render it visible, while we might comment on the others, but we leave them be”. Partly for tactical or strategic reasons, too. It’s to do with the fact that when we are to communicate something, it’s better not to have too many different things”

Also, the Road Directorate and the AIBN have decided that there must also be some collaboration prior to the issuing of safety recommendations:

“lately I and [the director of AIBN ] have agreed that for every report, we’ll have a meeting to discuss recommendations, and then we also have an opportunity to influence how these recommendations are formulated, so that we either have some action space, or we can formulate it in such a way that we know that it will be carried out. We do have a four-year action programme and budgets, which means we are really quite tied up, and if we can make the recommendation fit into a budget or an action plan, this makes it much easier for us.”

This is an approach that might to some extent water down the innovative aspect of the AIBN narratives, but on the other hand, it makes it more likely that the stories told will have an epilogue that is satisfactory to more parties.
PERCEPTION OF UNSAFE BEHAVIOR OF ROAD USERS*

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ABSTRACT:
A check-list of 150 items to measure unsafe behaviour of road users based on the third person principle was constructed. This study tool was applied on a final sample of 7058 drivers in twelve out of forty eight districts in Algeria. Subjects were asked to mark both the frequency and the degree of danger of each behavior (item) on two different scales of five points.

The results were used to classify the 150 items in descending order in terms of their means for their frequency and their degree of danger. It was found that the frequencies of unsafe behaviors are not limited to the driver only, but expanded to cover all road users. It seems that the ordering of the unsafe behaviours is affected by daily social habits and cultural characteristics of the population. This situation might be related the ambiguity of the meaning of the road to the Algerian individual who uses the road according to his spontaneous needs without referring to any norms or references but relying on his own interpretations which do not usually go with the road right. It was concluded from the high values of means that drivers realise the danger of unsafe behaviours well, despite the fact that they do not respect the traffic rules and laws in reality.

Moreover, to combine the frequency and the degree of danger, the results were treated by using a syntax program on the SPSS package to develop a matrix of nine categories of road users’ behavior after reducing the results on both scales to only three points for each. It was then possible to obtain the distribution of all these behaviors on the nine combinations of the matrices, but most items that had high scores were mainly on the following three categories:

1. Frequent and dangerous behavior,
2. Average frequent and dangerous behavior
3. Less frequent and dangerous behavior.

When the technique of factor analysis was applied to the results, it was found that the 150 items are well distributed in nine factors covering behaviors of drivers, cyclists, motorcyclists and pedestrians as follows:

1. Dangerous manoeuvrings by drivers.
2. Lack of education and culture for road users.
3. Negligence among road users.
4. Unsafe driving in urban region.
5. Lack of engagement & responsibility among drivers.
7. Uncivilised behavior.
8. Lack of engagement & responsibility for cyclists and motorcyclists.
9. Unsafe social phenomenon.

1. INTRODUCTION:
Despite the mobilization of many official and unofficial institutions to increase consciousness about the danger of road, in order to promote public awareness about education and culture of road safety, and despite introducing new rigorous law in 2004, as well as the execution of the technical control on vehicles, the introduction of a number of road accidents and its victims are increasing as is shown in table 1. This situation has become a dilemma for
the Algerian government especially with the big rising number of vehicles and fast developments and changes that Algeria is going through, so this growing problem is not limited only to the number of injured and victims, but also has its drawbacks on the economical and social activities in general and the control of road traffic in particular.

In this same context, Boudrifa et al (2007) found that 92.5% of drivers explain the non respect of traffic law by the lack of road education and culture, and 86.4% of them relate it to the lack of learning to drive, while 85.9% of them refer to the fact that the drivers rely on their personnel relation to escape from sanction. This attitude is also confirmed by 85.2% of individuals of the study sample who point out the lack of rigorous application of sanctions on drivers who do not respect the highway code. In addition, 84.5% referred to drivers risk taking and adventures, while 75.9% believe that the traffic law will never be applied. Beside 75.2% who think that there will be a kind of tolerance according to the social status of the driver, his sex and the type of his car. The question should therefore be raised on what are the factors and motives of unsafe behaviors of road users? However, to answer this question one needs to know or determine what are called unsafe behaviors of road users in a scientific way before looking for the factors and motives behind them. The present paper will explore the results of these kinds of unsafe behaviors.

Table 1, Statistics of the corporal accidents in four years

<table>
<thead>
<tr>
<th>Type of damage</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporal accidents</td>
<td>39233</td>
<td>40885</td>
<td>41175</td>
<td>42673</td>
</tr>
<tr>
<td>injured</td>
<td>58082</td>
<td>60120</td>
<td>61139</td>
<td>64708</td>
</tr>
<tr>
<td>Victims</td>
<td>3711</td>
<td>4120</td>
<td>4177</td>
<td>4422</td>
</tr>
</tbody>
</table>

2. METHOD:

2.1. Study Tool:

After carrying a series of interviews and preliminary studies, A checklist of 150 items to measure unsafe behaviour of road users based on the third person principle was constructed. Subjects were asked to mark the frequency of each behaviour (item) on a scale of five points (never, rarely, sometimes, most times, always), as well as its degree of danger on a five point scale (absolutely no danger, not dangerous, average danger, dangerous, very dangerous).

The aims of the present checklist are:
1. Assemble different data about unsafe behavior of road users in order to determine the most frequent and the most dangerous unsafe behaviors in drivers’ views.
2. Sort out matrices of unsafe behaviors of road users in terms of frequency and degree of danger.
3. Bring together these behaviors in factors by applying the technique of factor analysis in order to be taken into consideration for any future planning of strategies to prevent road accidents as well as to construct a questionnaire about factors and motives of unsafe behaviors of road users.
4. Work out the necessary conclusion and recommendations when planning any strategy to prevent road accidents.

2.2. Procedure:

Twelve out of 48 districts were chosen according to their order based on percentages of corporal accidents committed to the number of vehicles in each district. The geographical distribution was also taken into consideration by selecting each first three districts from the east, middle, west and south of Algeria, in order to have a distribution representing these different regions, by choosing districts which do not share the same border in order to obtain a representative distribution of each region. Moreover, the means available and the time allocated to this study were taken into consideration. Thus, the whole sample of the study was limited to 7000 drivers distributed over the twelve districts chosen as mentioned above. The number of individuals of the sample for each district was then sorted out by dividing the
number of the whole sample by the whole number of corporals accidents multiplied by the
number of accidents committed in each district. The checklist was written recto-verso in
Arabic and French to make it easier for drivers to answer it depending on the language they
master better.

2.3. Distribution of the Checklist:

7000 checklists in total were distributed over the twelve districts as mentioned above and
as shown in table: 2, in addition a number of checklists were added to that for each district to
compensate any expected lost or not valid ones during the application of the study, so the
final number distributed was 9082 checklists (see table: 2). Their distribution was carried out
mainly by postgraduate students, but also under graduate students studying in psychology or
sociology under the supervision of professors or assistant professors and all of them were
from the concerned district. They were all paid for this task. These applicants scattered in
places where drivers are expected to have free time to fill in and answer the checklists; mainly
bus and taxis drivers stations, vehicles insurances companies, vehicles’ technical control
stations and workshops for maintenance and reparations.

Table 2, Choice and Distribution of the checklist.

<table>
<thead>
<tr>
<th>Wilaya</th>
<th>Park auto</th>
<th>Accidents</th>
<th>Accident/Park</th>
<th>Sample sorted</th>
<th>Distributed</th>
<th>Retrieve</th>
<th>Valid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alger</td>
<td>812750</td>
<td>3425</td>
<td>0.42</td>
<td>1540</td>
<td>1692</td>
<td>1605</td>
<td>1555</td>
</tr>
<tr>
<td>Sétif</td>
<td>60762</td>
<td>2152</td>
<td>3.54</td>
<td>967</td>
<td>1300</td>
<td>814</td>
<td>779</td>
</tr>
<tr>
<td>Telemcen</td>
<td>101958</td>
<td>1560</td>
<td>1.53</td>
<td>701</td>
<td>800</td>
<td>697</td>
<td>656</td>
</tr>
<tr>
<td>Oran</td>
<td>180966</td>
<td>1357</td>
<td>0.74</td>
<td>610</td>
<td>750</td>
<td>439</td>
<td>422</td>
</tr>
<tr>
<td>Melbouaki</td>
<td>25997</td>
<td>1234</td>
<td>4.74</td>
<td>555</td>
<td>600</td>
<td>569</td>
<td>553</td>
</tr>
<tr>
<td>Chief</td>
<td>77264</td>
<td>1121</td>
<td>1.45</td>
<td>504</td>
<td>700</td>
<td>489</td>
<td>454</td>
</tr>
<tr>
<td>Béchar</td>
<td>66830</td>
<td>1065</td>
<td>1.59</td>
<td>479</td>
<td>900</td>
<td>722</td>
<td>689</td>
</tr>
<tr>
<td>Médéa</td>
<td>71771</td>
<td>963</td>
<td>1.34</td>
<td>433</td>
<td>600</td>
<td>451</td>
<td>429</td>
</tr>
<tr>
<td>Biskra</td>
<td>44662</td>
<td>939</td>
<td>2.10</td>
<td>422</td>
<td>580</td>
<td>551</td>
<td>545</td>
</tr>
<tr>
<td>Annaba</td>
<td>87874</td>
<td>723</td>
<td>0.82</td>
<td>325</td>
<td>400</td>
<td>330</td>
<td>313</td>
</tr>
<tr>
<td>Ourgla</td>
<td>47632</td>
<td>696</td>
<td>1.46</td>
<td>313</td>
<td>500</td>
<td>430</td>
<td>419</td>
</tr>
<tr>
<td>Béchar</td>
<td>19457</td>
<td>336</td>
<td>1.72</td>
<td>151</td>
<td>260</td>
<td>258</td>
<td>244</td>
</tr>
<tr>
<td>Total</td>
<td>1597923</td>
<td>15571</td>
<td>21.45</td>
<td>7000</td>
<td>9082</td>
<td>7355</td>
<td>7058</td>
</tr>
</tbody>
</table>

2.4. Statistical Technique Used:
The Statistical techniques used in the present study are:
- Percentages, means and standards deviations to distribute the frequency of unsafe
  behavior of road users as well as their degrees of gravity.
- Factor analysis to assemble these unsafe behaviors in order to use it in further study to
determine factors and motives of unsafe behaviors of road users.
- a syntax program on the SPSS package to develop a matrix of nine categories of road
  users of combined degree of frequency and gravity of unsafe behavior.

3. RESULTS:

3.1. Order of unsafe behaviors by road users according to their frequency:
The data were used to obtain the means, standards deviations and the total points for each
item. They were classified by their means in descending order, the items that obtain means
more than 3, were considered as frequent behaviours. 71 out of 150 items have means more or
equal to 3, the first ten most frequent behaviours of road users are shown in Table 3. It seems
that the ordering of the unsafe behaviours is affected by daily social habits and cultural
characteristics of the population. This situation might be related the ambiguity of the meaning
of the road to the Algerian individual who uses the road according to his spontaneous needs
without referring to any norms or references but relying on his own interpretations. Moreover
the variety of the most frequent items shows that the responsibility of unsafe behaviours is not
limited only to vehicles drivers, but shared by road users as well as other parties instead of
turning around the driver and the Ministry of transport. The results of the present study go
with the critics of previous studies by Summala & Naatanen (1976), who pointed out that there is a tendency in blaming road users about road accidents without looking out the responsibility of administrative staffs and road designers, as well as concentrating on the direct causes of road accidents instead of enlarging the matter to the complicated interaction between road users and environmental factors or other variables related to the road and vehicle in terms of man – environment –machine. This view was also supported by Klein (1977), who pointed out that studies about road accidents should give great attention to the interaction between the individual and his environment.

Table 3, Order of the eight first unsafe behaviours of road users according to the frequency.

<table>
<thead>
<tr>
<th>items</th>
<th>Mean</th>
<th>Std.</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The use of pavement for commercial or personal purposes</td>
<td>3.64</td>
<td>1.207</td>
<td>25682</td>
</tr>
<tr>
<td>2. Doing some work on the road without putting it back to its original state</td>
<td>3.58</td>
<td>1.202</td>
<td>25339</td>
</tr>
<tr>
<td>3. No reparation is done by the maintenance workers in the road</td>
<td>3.58</td>
<td>1.212</td>
<td>25288</td>
</tr>
<tr>
<td>4. Mentally sick and homeless people wandering in streets and roads</td>
<td>3.56</td>
<td>1.178</td>
<td>25133</td>
</tr>
<tr>
<td>5. The non –use of hamlet by cyclists and motorcyclists or their companions</td>
<td>3.51</td>
<td>1.237</td>
<td>24786</td>
</tr>
<tr>
<td>6. Doing the maintenance work during traffic rash hours</td>
<td>3.42</td>
<td>1.202</td>
<td>24121</td>
</tr>
<tr>
<td>7. Sudden and frequent Stopping of taxis</td>
<td>3.39</td>
<td>1.196</td>
<td>23912</td>
</tr>
<tr>
<td>8. The non-respect of traffic rules by cyclists and motorcyclists</td>
<td>3.34</td>
<td>1.204</td>
<td>23574</td>
</tr>
<tr>
<td>9. Non-use of Footbridge by pedestrians</td>
<td>3.34</td>
<td>1.144</td>
<td>23602</td>
</tr>
<tr>
<td>10. Audacity of Drivers in sports and wedding convoy</td>
<td>3.33</td>
<td>1.312</td>
<td>23536</td>
</tr>
</tbody>
</table>

3.2. Order of unsafe behaviors by road users according to the degree of danger.

The same treatment and principles as those above were applied to data about Classification of unsafe behaviors by road users according to the degree of danger. All 150 items had means above 3 ranging from 3.57 to 4.54, the first ten most dangerous behaviors of road users are shown in Table 4. The values of the standards deviations of all items are quiet low and close which could mean that drivers have similar perception to the degree of danger of unsafe behaviors presented in the checklist. Moreover, what might be concluded from the high values of means is that drivers realise well the danger of unsafe behaviours, and if so, why don’t they respect the traffic rules and laws then? Any way full attention should be given to these behaviours as classified in order according to the degree of danger for any future preventive actions or considering further studies or treatments, for example, how to explore these dangerous behaviours in terms of their frequency instead of treating them separately?

Table: 4. Order of the ten first unsafe behaviors of road users according to the degree of danger.

<table>
<thead>
<tr>
<th>items</th>
<th>Mean</th>
<th>Std.</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. overtaking in bends</td>
<td>4.54</td>
<td>.726</td>
<td>32014</td>
</tr>
<tr>
<td>2. Driving at night without using the vehicle lights</td>
<td>4.49</td>
<td>.759</td>
<td>31721</td>
</tr>
<tr>
<td>3. pedestrians crossing carriage ways</td>
<td>4.49</td>
<td>.758</td>
<td>31698</td>
</tr>
<tr>
<td>4. Parking of vehicles at bends</td>
<td>4.44</td>
<td>.753</td>
<td>31318</td>
</tr>
<tr>
<td>5. not controlling the tyres pressure</td>
<td>4.44</td>
<td>.752</td>
<td>31347</td>
</tr>
<tr>
<td>6. Children playing in the road or near it</td>
<td>4.43</td>
<td>.763</td>
<td>31275</td>
</tr>
<tr>
<td>7. small children crossing the road alone out of pedestrian crossing</td>
<td>4.42</td>
<td>.776</td>
<td>31214</td>
</tr>
<tr>
<td>8. Executing a dangerous overtaking</td>
<td>4.42</td>
<td>.779</td>
<td>31188</td>
</tr>
<tr>
<td>9. Executing dangerous manoeuvre while driving</td>
<td>4.41</td>
<td>.796</td>
<td>31121</td>
</tr>
<tr>
<td>10. Non adaptation of speed according to the angle of the bent</td>
<td>4.41</td>
<td>.752</td>
<td>31128</td>
</tr>
</tbody>
</table>

3.3. Order of unsafe behaviors by road users based on the combination of degree of danger and frequency.

After reducing the results on both scales into only three points for each, Subjects’ answers on “never” and “rarely” were considered as “Less Frequent behaviour”, while answers on “most times” and “always” as “Frequent behaviour” and finally answers on sometimes were regarded as “Average Frequent behaviour”. The same procedure was applied on the scale of danger, so subjects’ answers on “absolutely no danger” and “less dangerous” were considered as “Not dangerous behaviours”, while answers on “dangerous” and “very dangerous” as “Dangerous behaviours” and finally answers on average danger were regarded as “average
dangerous behaviours”. Frequency of behaviour was then related to the degree on danger by using matrices with two entries which were therefore used to obtain nine combinations. This was done by using a syntax program on the SPSS package to develop matrix of nine categories of road users’ behaviours. as referred to in table 5.

Table 5, Combination frequency and degree of danger for Matrices of unsafe behaviors of road users.

<table>
<thead>
<tr>
<th>Original scale</th>
<th>Reduced scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>always</td>
<td>F1. Frequent behaviour</td>
</tr>
<tr>
<td>most times</td>
<td>F2. Average Frequent behaviour</td>
</tr>
<tr>
<td>sometimes</td>
<td>F3. Less Frequent behaviour</td>
</tr>
<tr>
<td>rarely</td>
<td>D1. Not dangerous behaviour</td>
</tr>
<tr>
<td>never</td>
<td>D2. average dangerous behaviour</td>
</tr>
<tr>
<td>absolutely no danger</td>
<td>D3. Dangerous behaviour</td>
</tr>
</tbody>
</table>

The distribution of all these behaviors on the nine combinations of the matrices showed that most items had high scores mainly on the following three categories:
1. Frequent and dangerous behavior,
2. Average frequent and dangerous behavior
3. Less frequent and dangerous behavior.

Hence only these three categories will be treated in the following three sections, for example distribution of ten behaviors on the nine combinations of the matrices of unsafe behaviors of road users belonging to one of the three categories cited above depending on its highest percentage are shown in tables: 6, 7 & 8. The items sorted out for each category were classified in descending order as it will be clarified in the next three sections.

3.4. Frequent and dangerous behaviors of road users.

The number of items sorted out as frequent and dangerous behaviors of road users based on their highest percentages is 63 items; they were classified in descending order. The first ten are shown in table 6. What might distinguish these frequent and dangerous behaviors is that it covers different categories of road users. Hence, drivers have classified a number of phenomena and unsafe behaviours in road as it has indirect relation with road safety.

Table: 6. Ordering of the ten first Frequent & Dangerous behaviors of road users

<table>
<thead>
<tr>
<th>Behaviours</th>
<th>Freq</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The non-use of hamlet by cyclists and motorcyclists or the companions.</td>
<td>53</td>
<td>245</td>
<td>3097</td>
<td>44</td>
<td>292</td>
<td>1690</td>
<td>48</td>
<td>160</td>
<td>1429</td>
<td></td>
</tr>
<tr>
<td>2. No reparation is done by the maintenance workers in the road.</td>
<td>113</td>
<td>442</td>
<td>3279</td>
<td>72</td>
<td>390</td>
<td>1427</td>
<td>67</td>
<td>214</td>
<td>1054</td>
<td></td>
</tr>
<tr>
<td>3. Mentally sick and homeless people wandering in streets and roads</td>
<td>143</td>
<td>358</td>
<td>3332</td>
<td>67</td>
<td>336</td>
<td>1489</td>
<td>53</td>
<td>158</td>
<td>1122</td>
<td></td>
</tr>
<tr>
<td>4. Doing some work on the road without putting it back to its original state</td>
<td>113</td>
<td>442</td>
<td>3279</td>
<td>72</td>
<td>390</td>
<td>1427</td>
<td>67</td>
<td>214</td>
<td>1054</td>
<td></td>
</tr>
<tr>
<td>5. The non-respect of traffic rules by cyclists and motorcyclists</td>
<td>53</td>
<td>245</td>
<td>3097</td>
<td>44</td>
<td>292</td>
<td>1690</td>
<td>48</td>
<td>160</td>
<td>1429</td>
<td></td>
</tr>
<tr>
<td>6. Audacity of Driver in sports and wedding convoy</td>
<td>83</td>
<td>289</td>
<td>3046</td>
<td>71</td>
<td>353</td>
<td>1341</td>
<td>69</td>
<td>246</td>
<td>1560</td>
<td></td>
</tr>
<tr>
<td>7. The use of pavement for commercial or personal purposes</td>
<td>328</td>
<td>736</td>
<td>3020</td>
<td>104</td>
<td>398</td>
<td>1193</td>
<td>80</td>
<td>217</td>
<td>982</td>
<td></td>
</tr>
<tr>
<td>8. Children playing in the road or near it</td>
<td>68</td>
<td>160</td>
<td>2956</td>
<td>47</td>
<td>268</td>
<td>2047</td>
<td>46</td>
<td>150</td>
<td>1316</td>
<td></td>
</tr>
<tr>
<td>9. Sudden engagement of cyclists and motorcyclists in front of vehicles</td>
<td>79</td>
<td>209</td>
<td>2928</td>
<td>48</td>
<td>301</td>
<td>1803</td>
<td>68</td>
<td>196</td>
<td>1426</td>
<td></td>
</tr>
<tr>
<td>10. Doing the maintenance work during traffic rush hours</td>
<td>125</td>
<td>422</td>
<td>2891</td>
<td>80</td>
<td>457</td>
<td>1466</td>
<td>69</td>
<td>262</td>
<td>1286</td>
<td></td>
</tr>
</tbody>
</table>

The distribution of all these behaviors on the nine combinations of the matrices showed that most items had high scores mainly on the following three categories:
1. Frequent and dangerous behavior,
2. Average frequent and dangerous behavior
3. Less frequent and dangerous behavior.

Hence only these three categories will be treated in the following three sections, for example distribution of ten behaviors on the nine combinations of the matrices of unsafe behaviors of road users belonging to one of the three categories cited above depending on its highest percentage are shown in tables: 6, 7 & 8. The items sorted out for each category were classified in descending order as it will be clarified in the next three sections.
3.5. Average frequencies and dangerous behavior

Only sixteen (16) items with average percentage were classified under average frequent and dangerous behaviours. It should be noticed as well that more than its first third covers the behaviours of pedestrians mainly crossing the road, the rest of the other items describe few of drivers’ behaviours, but also that of their passengers like asking them to go faster or stop randomly anywhere (see Table 7).

Table: 7. Order of the ten first Average Frequent & Dangerous behaviors of road users

<table>
<thead>
<tr>
<th>Comportements</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pedestrians crossing the road in a bent</td>
<td>51</td>
<td>117</td>
<td>1631</td>
<td>42</td>
<td>297</td>
<td>2478</td>
<td>44</td>
<td>169</td>
<td>2229</td>
</tr>
<tr>
<td>%</td>
<td>7,1</td>
<td>1,7</td>
<td>23,1</td>
<td>0,6</td>
<td>4,2</td>
<td>35,1</td>
<td>0,6</td>
<td>2,4</td>
<td>31,6</td>
</tr>
<tr>
<td>2. Pedestrians crossing roadway without light</td>
<td>73</td>
<td>149</td>
<td>1723</td>
<td>71</td>
<td>309</td>
<td>2372</td>
<td>46</td>
<td>221</td>
<td>2094</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>2,1</td>
<td>24,4</td>
<td>1,0</td>
<td>4,4</td>
<td>33,6</td>
<td>0,7</td>
<td>3,1</td>
<td>29,7</td>
</tr>
<tr>
<td>3. Pedestrians who cross the road in an unpredictable way</td>
<td>62</td>
<td>155</td>
<td>2305</td>
<td>63</td>
<td>289</td>
<td>2362</td>
<td>62</td>
<td>178</td>
<td>1602</td>
</tr>
<tr>
<td>%</td>
<td>9,2</td>
<td>2,2</td>
<td>32,7</td>
<td>9,1</td>
<td>4,1</td>
<td>33,5</td>
<td>0,6</td>
<td>2,5</td>
<td>22,7</td>
</tr>
<tr>
<td>4. Pedestrians who cross the road in diagonal trajectory</td>
<td>63</td>
<td>209</td>
<td>2058</td>
<td>47</td>
<td>418</td>
<td>2233</td>
<td>63</td>
<td>246</td>
<td>1721</td>
</tr>
<tr>
<td>%</td>
<td>9,3</td>
<td>3,0</td>
<td>29,2</td>
<td>7,5</td>
<td>9,1</td>
<td>31,6</td>
<td>0,9</td>
<td>3,5</td>
<td>24,4</td>
</tr>
<tr>
<td>5. Pedestrians who take tunnels and bridges made only for vehicles</td>
<td>65</td>
<td>164</td>
<td>1859</td>
<td>48</td>
<td>314</td>
<td>2226</td>
<td>68</td>
<td>232</td>
<td>2082</td>
</tr>
<tr>
<td>%</td>
<td>9,2</td>
<td>2,3</td>
<td>26,3</td>
<td>7,7</td>
<td>5,9</td>
<td>31,3</td>
<td>0,8</td>
<td>3,8</td>
<td>25,6</td>
</tr>
<tr>
<td>6. Pedestrians who cross the roadway in the middle of junctions</td>
<td>64</td>
<td>214</td>
<td>1985</td>
<td>47</td>
<td>414</td>
<td>2207</td>
<td>55</td>
<td>266</td>
<td>1806</td>
</tr>
<tr>
<td>%</td>
<td>9,9</td>
<td>3,0</td>
<td>28,1</td>
<td>7,5</td>
<td>9,1</td>
<td>31,3</td>
<td>0,8</td>
<td>3,8</td>
<td>25,6</td>
</tr>
<tr>
<td>7. Passengers who put pressure on the driver to go faster</td>
<td>92</td>
<td>236</td>
<td>1926</td>
<td>83</td>
<td>351</td>
<td>2184</td>
<td>90</td>
<td>256</td>
<td>1840</td>
</tr>
<tr>
<td>%</td>
<td>1,3</td>
<td>3,3</td>
<td>27,3</td>
<td>1,2</td>
<td>6,0</td>
<td>30,9</td>
<td>1,3</td>
<td>3,6</td>
<td>26,1</td>
</tr>
<tr>
<td>8. Passengers who bend out of the vehicle in traffic way</td>
<td>94</td>
<td>260</td>
<td>2014</td>
<td>71</td>
<td>441</td>
<td>2143</td>
<td>72</td>
<td>223</td>
<td>1740</td>
</tr>
<tr>
<td>%</td>
<td>1,3</td>
<td>3,7</td>
<td>28,5</td>
<td>1,0</td>
<td>6,2</td>
<td>30,4</td>
<td>1,0</td>
<td>3,2</td>
<td>24,7</td>
</tr>
<tr>
<td>9. Sudden reduction of the vehicle’s speed</td>
<td>84</td>
<td>225</td>
<td>1634</td>
<td>116</td>
<td>534</td>
<td>2096</td>
<td>71</td>
<td>291</td>
<td>2007</td>
</tr>
<tr>
<td>%</td>
<td>1,2</td>
<td>3,2</td>
<td>23,2</td>
<td>1,6</td>
<td>7,6</td>
<td>29,7</td>
<td>1,0</td>
<td>4,1</td>
<td>28,4</td>
</tr>
<tr>
<td>10. Passengers who put pressure on the driver to stop randomly in non secure way.</td>
<td>88</td>
<td>244</td>
<td>1982</td>
<td>70</td>
<td>393</td>
<td>2081</td>
<td>79</td>
<td>235</td>
<td>1886</td>
</tr>
<tr>
<td>%</td>
<td>1,2</td>
<td>3,5</td>
<td>28,1</td>
<td>1,0</td>
<td>5,6</td>
<td>29,5</td>
<td>1,1</td>
<td>3,3</td>
<td>26,7</td>
</tr>
</tbody>
</table>

3.6. Less frequent and dangerous behavior.

Sixty (60) items out of those seventy one (71), classified as less frequent and dangerous behaviours are related to drivers’ behaviours, especially the first ten items that are shown in table 8. It should be noticed that these less frequent and dangerous behaviours have scored very high percentages compared to the two previous categories above. For example, 50.5 % of the present study’ subjects describe the item: ‘stopping on the left side of the carriage way’ as less frequent and dangerous behaviours.

Table: 8. Ordering of the eight first less Frequent & Dangerous behaviors of road users

<table>
<thead>
<tr>
<th>behaviors</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. stopping on the far left side of carriage ways</td>
<td>68</td>
<td>175</td>
<td>1155</td>
<td>51</td>
<td>253</td>
<td>1506</td>
<td>58</td>
<td>228</td>
<td>3564</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>2,5</td>
<td>16,4</td>
<td>7,6</td>
<td>3,6</td>
<td>21,3</td>
<td>8,1</td>
<td>3,2</td>
<td>50,5</td>
</tr>
<tr>
<td>2. Driving a vehicle at night without using lights</td>
<td>55</td>
<td>135</td>
<td>1189</td>
<td>42</td>
<td>232</td>
<td>1683</td>
<td>57</td>
<td>186</td>
<td>3479</td>
</tr>
<tr>
<td>%</td>
<td>0,8</td>
<td>1,9</td>
<td>16,8</td>
<td>6,3</td>
<td>3,3</td>
<td>23,8</td>
<td>8,8</td>
<td>2,6</td>
<td>49,3</td>
</tr>
<tr>
<td>3. stopping in the middle of junctions</td>
<td>69</td>
<td>185</td>
<td>1055</td>
<td>60</td>
<td>300</td>
<td>1727</td>
<td>67</td>
<td>272</td>
<td>3326</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>2,6</td>
<td>14,9</td>
<td>9,4</td>
<td>4,3</td>
<td>24,5</td>
<td>9,9</td>
<td>3,9</td>
<td>47,1</td>
</tr>
<tr>
<td>4. Driving backward at junctions</td>
<td>72</td>
<td>229</td>
<td>1077</td>
<td>33</td>
<td>393</td>
<td>1712</td>
<td>53</td>
<td>207</td>
<td>3287</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>3,2</td>
<td>15,2</td>
<td>5,5</td>
<td>5,6</td>
<td>24,3</td>
<td>8,9</td>
<td>2,9</td>
<td>46,6</td>
</tr>
<tr>
<td>5. Non respect of traffic rules by drivers even in front of policemen</td>
<td>73</td>
<td>164</td>
<td>1034</td>
<td>67</td>
<td>330</td>
<td>1340</td>
<td>271</td>
<td>527</td>
<td>3251</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>2,3</td>
<td>14,3</td>
<td>9,4</td>
<td>4,7</td>
<td>19,0</td>
<td>5,8</td>
<td>7,5</td>
<td>46,1</td>
</tr>
<tr>
<td>6. driving in the forbidden direction</td>
<td>59</td>
<td>183</td>
<td>1270</td>
<td>49</td>
<td>344</td>
<td>1656</td>
<td>82</td>
<td>294</td>
<td>3121</td>
</tr>
<tr>
<td>%</td>
<td>0,8</td>
<td>2,6</td>
<td>18,0</td>
<td>7,4</td>
<td>4,9</td>
<td>23,5</td>
<td>1,2</td>
<td>4,2</td>
<td>44,2</td>
</tr>
<tr>
<td>7. overtaking at Junctions</td>
<td>69</td>
<td>170</td>
<td>1264</td>
<td>42</td>
<td>292</td>
<td>1936</td>
<td>51</td>
<td>181</td>
<td>3051</td>
</tr>
<tr>
<td>%</td>
<td>1,0</td>
<td>2,4</td>
<td>17,9</td>
<td>6,4</td>
<td>4,1</td>
<td>27,4</td>
<td>7,2</td>
<td>2,6</td>
<td>43,2</td>
</tr>
<tr>
<td>8. Getting on or off the vehicle while it is running</td>
<td>61</td>
<td>187</td>
<td>1399</td>
<td>67</td>
<td>300</td>
<td>1767</td>
<td>74</td>
<td>225</td>
<td>2979</td>
</tr>
<tr>
<td>%</td>
<td>0,9</td>
<td>2,6</td>
<td>19,8</td>
<td>9,4</td>
<td>4,3</td>
<td>25,0</td>
<td>1,0</td>
<td>3,2</td>
<td>42,2</td>
</tr>
<tr>
<td>9. Not wearing medical glasses despite their absolute necessity</td>
<td>67</td>
<td>197</td>
<td>1264</td>
<td>64</td>
<td>380</td>
<td>1678</td>
<td>102</td>
<td>383</td>
<td>2924</td>
</tr>
<tr>
<td>%</td>
<td>0,9</td>
<td>2,8</td>
<td>17,9</td>
<td>5,4</td>
<td>5,4</td>
<td>23,8</td>
<td>1,4</td>
<td>5,4</td>
<td>41,4</td>
</tr>
<tr>
<td>10. Parking vehicles on a bridge</td>
<td>81</td>
<td>181</td>
<td>1164</td>
<td>80</td>
<td>428</td>
<td>1622</td>
<td>143</td>
<td>456</td>
<td>2903</td>
</tr>
<tr>
<td>%</td>
<td>1,1</td>
<td>2,6</td>
<td>16,3</td>
<td>1,1</td>
<td>6,1</td>
<td>23,0</td>
<td>2,0</td>
<td>6,5</td>
<td>41,1</td>
</tr>
</tbody>
</table>
3.7. Factor analysis of matrices of unsafe road behaviors of road users:

By using the Statistical package for social sciences and before carrying the analysis the principle components, the factorability of data were evaluated and as shown in table 9, the value of Kaiser is 0.993, which is more than the recommended value estimated at 0.6. Moreover, the test of Bartlett reached the significant level.

Table: 9, KMO and Bartlett's Test

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th>Bartlett's Test of Sphericity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Approx. Chi-Square</td>
</tr>
<tr>
<td></td>
<td>df</td>
</tr>
<tr>
<td></td>
<td>Sig.</td>
</tr>
</tbody>
</table>

The analysis of the main components revealed the existence of 16 components. The value of its potential root is more than 1, and explains 53.32 % of the total variance but only 9 components were kept for further analysis and study which explained 48.10 % of the total variance. It was found that the 150 items are well distributed in nine factors covering behavior of drivers, cyclists, motorcyclists and pedestrians as follows:

3.7.1. Factor 1: Dangerous manoeuvrings by drivers.

This factor explained (32.98 %) of the variance between individuals of the sample of the present study. It concerns essentially dangerous manoeuvres executed by drivers of vehicles which present many kinds of risk taking in driving that usually end up by committing dangerous road accidents. This factor includes 26 items as shown below; they confirm the earlier results of the previous different axes in which the degree of these dangerous behaviors was raised by drivers of the study sample by classifying them in the first places according to the degree of danger. It is therefore necessary to concentrate on these behaviors and give them full attention in the framework to face the increasing number of road accidents in order to take the suitable actions to stop it or at last reduce it. On the other hand, there is a need to raise the level of training in driving to go with the modern requirements of this task.

<table>
<thead>
<tr>
<th>Items</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Executing a dangerous overtaking</td>
<td>.565</td>
</tr>
<tr>
<td>2. Bad use of lights in meeting or in intersection</td>
<td>.550</td>
</tr>
<tr>
<td>3. overtaking in bends</td>
<td>.547</td>
</tr>
<tr>
<td>4. Drivers do not drive at the extreme right of the road.</td>
<td>.544</td>
</tr>
<tr>
<td>5. Driving a vehicle with smooth tyres.</td>
<td>.534</td>
</tr>
<tr>
<td>6. A driver who does not let another driver overtake him.</td>
<td>.532</td>
</tr>
<tr>
<td>7. Non respect of the safe distance between two vehicles.</td>
<td>.525</td>
</tr>
<tr>
<td>8. Non respect of the stop sign.</td>
<td>.524</td>
</tr>
<tr>
<td>9. Release of a thick smoke at the rear of the vehicle.</td>
<td>.520</td>
</tr>
<tr>
<td>10. non control of the tyres pressure</td>
<td>.518</td>
</tr>
<tr>
<td>11. Non adaptation of speed according to the angle of the bent</td>
<td>.517</td>
</tr>
<tr>
<td>12. Audacity of Drivers in sports and wedding convoys</td>
<td>.516</td>
</tr>
<tr>
<td>13. Driving with closed or broken side-view mirror.</td>
<td>.515</td>
</tr>
<tr>
<td>14. Driving a tractor in the middle of the road and being in the way of road traffic.</td>
<td>.511</td>
</tr>
<tr>
<td>15. Executing a dangerous manoeuvre while driving</td>
<td>.492</td>
</tr>
<tr>
<td>16. Driving in a state of nervousness and high emotion.</td>
<td>.492</td>
</tr>
<tr>
<td>17. Parking of vehicles at bends</td>
<td>.490</td>
</tr>
<tr>
<td>18. Stopping a bus anywhere to take passengers</td>
<td>.479</td>
</tr>
<tr>
<td>19. Parking vehicles on a bridge</td>
<td>.478</td>
</tr>
<tr>
<td>20. Driving lorries and buses on the extreme left side of the road.</td>
<td>.474</td>
</tr>
<tr>
<td>21. Crossing the continuous line.</td>
<td>.471</td>
</tr>
<tr>
<td>22. Race between two vehicles.</td>
<td>.470</td>
</tr>
<tr>
<td>23. Drivers who stay deliberately in the way of another driver.</td>
<td>.461</td>
</tr>
<tr>
<td>24. Not wearing medical glasses despite their absolute necessity</td>
<td>.455</td>
</tr>
<tr>
<td>25. Non use of turning lights to get off or to change the line.</td>
<td>.426</td>
</tr>
<tr>
<td>26. Stopping to see an accident.</td>
<td>.360</td>
</tr>
</tbody>
</table>

3.7.2. Factor 2: Lack of education and culture for road users.

This factor explained (4.92 %), of the variance between individuals of the sample of the present study. The 21 items of this factor as shown below, point out the absence of road safety
education and culture among road users. It is therefore necessary to prepare a full national strategy which permits the participation of different official and unofficial sectors and organizations to participate in the global operation of mobilization and increasing consciousness about road concept and its danger. In order to develop the public awareness about education and culture of road safety and incorporate it in reality, for example introducing road safety education at school, pointing out the role of religion in road education, reparation and amelioration of roads, placing barriers and passageways to direct pedestrians, looking after those categories that usually coexist in the road and present a danger on themselves and on the rest of road users, Such as children, beggars and homeless people. In addition to the necessity of introducing special training programs for maintenance workers as well as for traffic policemen and trying in the same time to look for the necessary characteristics and personality traits for their selection.

<table>
<thead>
<tr>
<th>Items</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Doing some work on the road without putting it back to its original state</td>
<td>.690</td>
</tr>
<tr>
<td>2. Non reparation of road by the maintenance services.</td>
<td>.672</td>
</tr>
<tr>
<td>3. Doing the maintenance work during traffic rush hours</td>
<td>.662</td>
</tr>
<tr>
<td>4. Services of the public work do not cut down trees branches which are obstacles for the traffic way.</td>
<td>.660</td>
</tr>
<tr>
<td>5. Non removal of animals’ corpses in time by maintenance services.</td>
<td>.627</td>
</tr>
<tr>
<td>6. The use of pavement for commercial or personal purposes</td>
<td>.613</td>
</tr>
<tr>
<td>7. The existence of mentally sick and homeless people wandering in streets and roads.</td>
<td>.597</td>
</tr>
<tr>
<td>8. Non use of white gloves by Traffic policeman when directing traffic.</td>
<td>.566</td>
</tr>
<tr>
<td>9. small children crossing the road alone out of pedestrian crossing</td>
<td>.541</td>
</tr>
<tr>
<td>10. Pedestrians who cross the road without respecting the traffic lights.</td>
<td>.538</td>
</tr>
<tr>
<td>11. Pedestrians who roll a gas containers pushing them with their feet.</td>
<td>.538</td>
</tr>
<tr>
<td>12. Pedestrians who do not control the children who go with them when they are using the road.</td>
<td>.532</td>
</tr>
<tr>
<td>13. The use of ambiguous gestures by Traffic policeman while directing the traffic.</td>
<td>.511</td>
</tr>
<tr>
<td>14. Pedestrians who push a trolley or push chairs on the road reserved to vehicles.</td>
<td>.497</td>
</tr>
<tr>
<td>15. Pedestrians who do hitch-hiking in the middle of the road.</td>
<td>.481</td>
</tr>
<tr>
<td>16. Pedestrians who do not stop for a while on the pavement before crossing the road.</td>
<td>.479</td>
</tr>
<tr>
<td>17. Pedestrians who cross the road without respecting order of the Traffic policeman.</td>
<td>.465</td>
</tr>
<tr>
<td>18. Precipitation of pedestrians to go in front of vehicles.</td>
<td>.462</td>
</tr>
<tr>
<td>19. Pedestrians who cross the road in front of a bus right after getting off from it.</td>
<td>.448</td>
</tr>
<tr>
<td>20. Pedestrians who cross the road jerking between vehicles</td>
<td>.445</td>
</tr>
<tr>
<td>21. Children who circulate in the road on rollers skates.</td>
<td>.420</td>
</tr>
</tbody>
</table>

### 3.7.3. Factor 3: Negligence among road users.

This factor explained (2.57 %), of the variance between individuals sample of the present study. The 15 items of this factor as shown below cover the carelessness among road users. These items represent therefore a categorical contravention of road safety rules by conscience in the absence of factors of the social stability and safe social upbringing procedures. Perhaps it would rather be beneficial to deal with this factor by going back to two essential determinants in the social upbringing which represent the social control by the strict application of the traffic law on the one side, and on the other side, raising the public awareness about the danger of the road and the importance and value of the human life by doing so at the level of different social upbringing institutions like the family, schools, mosques, in addition to mobilizing all different civic sectors and organizations in the society in particular. Especially that recent studies have revealed that the dangerous behaviors in driving vehicles are affected by many institutions like those who sell cars joined with advertising opinions which help drivers to explore unsafe and dangerous behaviors by injecting higher levels of self confidence and insisting on the strength of the vehicle and the easy manipulation of its control (Brunel, 2002).

<table>
<thead>
<tr>
<th>Items</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Driving backward at junctions</td>
<td>.603</td>
</tr>
<tr>
<td>2. stopping on the far left side of carriage ways</td>
<td>.587</td>
</tr>
<tr>
<td>3. stopping in the middle of junctions</td>
<td>.568</td>
</tr>
<tr>
<td>4. Driving a vehicle at night without using lights</td>
<td>.537</td>
</tr>
</tbody>
</table>
5. Getting on or off the vehicle while it is running, 5.32
6. Overtaking at junction, 5.30
7. Non respect of the policemen’s orders by some drivers, 5.24
8. Driving in the forbidden direction, 5.10
9. Non respect of traffic rules by drivers even in front of policemen, 5.05
10. Carrying passengers in the rear boot of the vehicle, 4.76
11. Carrying dangerous products on the bicycle or motocycle, 4.60
12. Going backward from a secondary to a main road, 4.43
13. Overtaking in top of a hill, 4.43
14. Driving a vehicle with a mechanical problem at the level of wheels, 4.19
15. Pedestrians who get in behind a vehicle going backward, 4.10

3.7.4. Factor 4: Unsafe driving in urban area.

This factor explained (1.80 %), of the variance between individual of the sample of the present study. The 22 items shown below indicate the existence of a lot of unsafe behaviors in the urban area, which reflect the factor as very important in modern life and technological development. This is perhaps why the driver nowadays demonstrates a behavior based on saving more and more time through excessive speed or attempting to pass before the appearance of the red light or going faster when the green light shows up. These types of unsafe behaviors might well be responsible for the traffic jam that most Algerian towns are suffering from. It is therefore useful to emphasize on the importance of time and develop its management in the field of road traffic, as well as to take all necessary actions to promote road traffic system by appropriate planning of roads and introducing all different traffic signs and facilities especially those concerning the urban transports which might insure flexibility in the flow of traffic. This can make road users regain self-confidences to arrive to their target in reasonable time.

<table>
<thead>
<tr>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stopping on or near pedestrians crossing in a built-up area.</td>
</tr>
<tr>
<td>2. Non reduction of speed while approaching bends or intersections.</td>
</tr>
<tr>
<td>3. Non respect of the upper speed limit.</td>
</tr>
<tr>
<td>4. Overtaking on the pedestrians crossing in a built-up area.</td>
</tr>
<tr>
<td>5. Stopping at the proximity of the roads angles.</td>
</tr>
<tr>
<td>6. Excessive speed over 70 km/h in a built-up area.</td>
</tr>
<tr>
<td>7. Sudden exit from a secondary road without taking the necessary preventive precautions</td>
</tr>
<tr>
<td>8. Driving near schools without precaution</td>
</tr>
<tr>
<td>9. Stopping on the pavement to unload goods.</td>
</tr>
<tr>
<td>10. A driver who overtakes a queue of vehicles that are waiting to pass</td>
</tr>
<tr>
<td>11. Cutting the angle in a bend.</td>
</tr>
<tr>
<td>12. Stopping in a narrow road.</td>
</tr>
<tr>
<td>13. Drivers who try to go before the appearance of the red light.</td>
</tr>
<tr>
<td>14. Overtaking on the side of the inverse direction of a normal road.</td>
</tr>
<tr>
<td>15. Stopping in the second position to unload goods.</td>
</tr>
<tr>
<td>16. Driving away quickly as soon as the appearance of the green light.</td>
</tr>
<tr>
<td>17. Non reduction of speed when there are repairs on the road.</td>
</tr>
<tr>
<td>18. Doing some shopping on the road.</td>
</tr>
<tr>
<td>19. Turning right or left in a forbidden place.</td>
</tr>
<tr>
<td>20. Vehicles who are going down do not give way to vehicles going up.</td>
</tr>
<tr>
<td>21. Sudden deviation of a vehicle to correct its trajectory.</td>
</tr>
<tr>
<td>22. Sudden reduction of the vehicle’s speed</td>
</tr>
</tbody>
</table>

3.7.5. Factor 5: Lack of engagement and responsibility among drivers.

This factor has participated in explaining the variance between individual of the sample of the present study by (1.39 %). The 21 items shown below describe the Lack of engagement and responsibility among drivers, which can be attributed as is revealed by the items cited below to the absence of social norms that can guide the individual behavior, beside the
absence of stereotypes’ behaviors. It is therefore necessary to promote the awareness of the social responsibility among drivers as well as to increase the level of training on the driving task.

### 3.7.6. Factor 6: Lack of engagement and responsibility among pedestrians.

This factor explained (1.20 %), of the variance between individual of the sample of the present study. The 13 items shown below indicate the existence of lack of engagement and responsibility among pedestrians, which raise the absolute needs to give much attention to pedestrian’s safety and develop the infrastructures that promote their right use of the road like the good design of pavement and different kinds of road crossings in way that it goes with what was found by different scientific studies as well as design levels reached by developed countries in this field. It is also necessary to intensify actions of public awareness in order to teach pedestrians and especially children how to cross the road, in addition to raising their level of consciousness about road danger and explaining to them their rights and their obligations on the road as well as the necessity to respect other road users’ rights as a civilized behavior required by modern road traffic.

**Items**

1. Pedestrians who cross the roadway in the middle of junctions
2. Pedestrians who cross the road in diagonal trajectory
3. Pedestrians crossing in a bent
4. Pedestrians crossing roadway without light
5. Pedestrians who cross the road in an unpredictable way
6. Pedestrians who jump over the barriers which direct the traffic.
7. Pedestrians who take tunnels and bridges made only for vehicles
8. Pedestrians crossing carriageways
9. Pedestrians who badly estimate the right time to cross the road.
10. Pedestrians who walk through underground passages.
11. Pedestrians who play on the road or near it.
12. Pedestrians who cross the road very slowly.
13. Breeders who do not control their animals in the moment of crossing the road.

### 3.7.7. Factor 7: Uncivilised behavior.

This factor explained (1.15 %), of the variance between individual of the sample of the present study. The 12 items shown below indicate the existence of uncivilised behaviors among road users, which is perhaps related to the excessive consuming of what modern technological has offered as products and facilities taking advantage of the technical side without regarding the civilized behaviors that go with the use of this technology. Perhaps these behaviors are based on the wrong beliefs that accidents can occur to others and not to
them, simply because they are under the protection of these technological means as it is the case for the airbag. This might be due to the lack of the social upbringing as it is illustrated by the behaviors shown below. They reflect the citizens’ reactions towards the institution of the social upbringing, and his perception that they are not interested in what they are doing through the fragility of social control means like security, justice, lack of religious motives and degradation of morals. This situation creates a dissonance and distance detachment between the citizen and the institutions responsible for the social upbringing, which makes him feel as outsider and his selfishness grows up, besides not adhering to norms. Hence this factor might draw the attention to the necessity for these institutions to take their full responsibilities.

Items
1. Using of mobile phone while driving , 542
2. Driver who stop in the middle of the road to talk to other people. , 504
3. Throwing bottles, boxes and left over of food , 504
4. Driver who do not respect other drivers , 500
5. excessive Load , 494
6. Non use of safety belt when driving , 484
7. A passenger who gets off the vehicle on left side of the vehicle. , 479
8. Non control of the state of the vehicle and the position of passengers before departure. , 460
9. Changing vehicle direction suddenly. , 455
10. Load not fixed or not covered. , 438
11. Overtaking on the pavement or on the edge of the road. , 406
12. Not taking a rest after a long journey. , 395

3.7.8. Factor 8: Lack of engagement and responsibility by cyclists and motorcyclists.

This factor has participated in explaining the variance between individuals of the sample of the present study by (1.09 %). The 10 items shown below describe the lack of engagement and responsibility among cyclists and motorcyclists. Hence, it appears that the rigorous application of traffic law on this category of road users is absolutely necessary. It will be the right solution to make the behavior formation corresponds to the social norms. In addition, it is much better to allocate special passageway for them, as well as forcing them to get driving license after special training and mobilization on the importance of respecting the high way code as well as traffic safety rules and regulations. It is also necessary to intensify actions of public awareness in order to mobilize all the population in general and parents who buy bicycles or motorcycles for their children to use it on the road without any special training or education, in particular. In addition to raising their level of consciousness about road danger and explaining to them their rights and their obligations on the road as well as the necessity to respect other road users’ rights as a civilized behavior required by modern road traffic.

Items
1. Cyclists and motorcyclists who do not respect the traffic lights. , 589
2. Cyclists and motorcyclists who circulate on the road with a lot of selfishness. , 580
3. Sudden engagement of cyclists and motorcyclists in front of vehicles , 574
4. Cyclists and motorcyclists who take a lot of space on the road. , 573
5. The non-respect of traffic rules by cyclists and motorcyclists , 558
6. Carrying persons in dangerous positions on bicycles or motorbikes. , 541
7. The non-use of hamlet by cyclists and motorcyclists or their companions , 536
8. Cyclists and motorcyclists who do dangerous exhibitions on the road. , 522
9. Cyclists and motorcyclists who drive on the pavements. , 506
10. Cyclists and motorcyclists who drive without using their lights to give signs. , 504


This factor has participated in explaining the variance between individual of the sample of the present study by (1.09 %). The 9 items shown below describe some of the unsafe social phenomenon among road users that is extracted from the culture of the society in the wrong use of road, things that indicate the big gap in road safety education and culture among the Algerian citizens in general. This requires the mobilization of different civic parties of the
society beside administrative authorities and institutions responsible for road organization and watching out that it is used for the right purposes.

Items
1. Beggars in the middle of the road.  .514
2. Sellers who expose their goods in the middle of the road, like selling newspapers. .506
3. Pedestrians who push the driver to go faster .472
4. Pedestrians who push the driver to stop Suddenly in a dangerous way .456
5. Pedestrians who bend out of the vehicle in traffic way. .452
6. Passengers who distract the attention of the driver continuously. .446
7. Carrying passengers together with goods in the rear of commercial vehicle. .436
8. Leaving children on their own in the vehicle. .406
9. Non-use of Footbridge by pedestrians .398

4. DISCUSSION:

It seems that unsafe behaviours are affected by daily social habits and cultural characteristics of the population. This situation might be related to the ambiguity of the meaning of the road to the Algerian individual who uses the road according to his spontaneous needs without referring to any norms or references but relying on his own interpretations instead. The results of the present study could be explained in the context of the theory of planned behaviour proposed by Ajzen (1985, 1991), which supposes that the human behaviour is based on three sorts of beliefs (Ajzen 1980, 1985, 2001, 2002, 2005; Johnson & Hall, 2005; De pelsmacker & Janssens, 2007): behavioral, normative and control beliefs. Moreover, the results of the present study show that the responsibility of unsafe behaviours is not limited only to vehicle drivers, but shared by road users as well as other parties instead of turning around the driver and the Ministry of transport. It is therefore necessary to take the suitable arrangements to share the responsibility in a vertical way from the national level to the regional, and in a horizontal way through the different private and public sectors as well as specialised groups. This can help to share responsibility and plan effective strategies allowing the adoption of regional and national programs for the reduction of the number of victims and at the same time allocating special budget for road safety (European Transport safety Council, 2001).

It is therefore necessary to prepare a full national strategy which permits the participation of different official and unofficial sectors and organizations to participate in the global operation of mobilization and increase consciousness about road concept and its danger in order to develop the public awareness about education and culture of road safety and incorporate it in reality. Moreover, It is useful to emphasize on the importance of time and develop its management in the field of road traffic, as well as to take all necessary actions to promote road traffic system by appropriate planning of roads and introducing all different traffic signs and facilities especially those concerning the urban transports which might insure flexibility in the flow of traffic. This can make road users regain self-confidence to arrive to their target in a reasonable time.

It is now known that accidents are the results of the interaction between many factors and that error committed by the road user is only one of these factors. This is based on the system approach which relies on the interaction of many factors that cause accident injuries. This new approach goes well with the various unsafe behaviours reported in the present study, which were expanded even to road maintenance. There is a necessity to good and effective organisation of road traffic, adaptation of economical trade and social activities and the organisation of working hours with the necessary fluidity of road traffic in order to create and prepare the suitable environment for the application of traffic law and its effective incorporation in reality (Elvik, R, 2002). Modern methods and means should also be used to pass on the message of the high way code to all road users by convincing them that the law and policemen are there to protect them (Horberry et al, 2006).
5. CONCLUSION & RECOMMENDATIONS:

It can be concluded that it is possible to change or direct unsafe behaviours of road users by various means or strategies and through different stages. For example, improving conception of pavement and pedestrians crossing and adapting them to the required norms may well convince at least the majority of them to use these facilities in the appropriate way. The same thing could be done for drivers by good conception of road and traffic signs...etc. It is therefore possible to put forward the main few recommendations as follow:

1. It is necessary to adopt the system approach which relies on the interaction of many factors that cause accident injuries, as it is now known that accidents are the results of the interaction between many factors and that error committed by the road user is only one of these factors.

2. Emphasising that the problem of road safety and the public awareness which goes with it is the responsibility of all, and any negligence from any side could spoil the efforts of other parties.

3. Promoting political consciousness-raising campaign and helping to introduce effective and scientific procedures in order to reduce the number of road accidents.

4. Adapting economical, commercial and social activities, and organising working hours in accordance to the fluidity of road traffic.

5. Trying to change some usual believes and habits of road users such as relying on personal relations to escape from sanctions, and the lack of rigorous application of sanctions against drivers who break the law, in addition to drivers’ beliefs of that the law will never be applied, and the idea of turning blind eye concerning the application of law according to some characteristics of the driver such as his sex, his social status or the type of vehicle.

6. Engaging discussion in order to look for different solutions to promote the level of road safety education and culture.

7. Working out a connection between the number of contraventions and the vehicle insurance

6. REFERENCES:


7. De pelsmacker, P ; & Janssens, w. (2007):


Contents session 3  Road Safety Plans and Strategies II

Australia’s New Approach to Road Safety: How is the Safe System Approach Being Implemented?
Blair Turner, ARRB Group, Australia

Organizing For Road Safety In Bangladesh: Some Challenges And Opportunities
Dr. Med. Mazharul Hoque, Department of Civil Engineering, BUET, Bangladesh

3 Step Generic Procedure To Assess Road Safety: A Case Study of Egypt
Dr. Khaled Abbas, roads & Transport Authority, Dubai, United Arab Emirates

Effective Road-Safety Policy Making in Lower Income Countries: Ten Principles from Social Systems Thinking
Alfredo del Valle, Universidad Alberto Hurtado, Santiago, Chile
Australia’s new approach to road safety: How is the Safe System approach being implemented?

Blair Turner, Principal Research Scientist, ARRB Group &
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Abstract

The Safe System approach has recently been adopted by Australia as the guiding principle for delivering road safety outcomes. This approach suggests (amongst other things) road users will make mistakes, and that they have a limited tolerance for surviving such events, or avoiding serious injury. Therefore, there is a need for a road system that is ‘forgiving’ of mistakes by road users. There is also a need to manage road users to ensure that they are alert and compliant.

Although the vision for this approach is clear, the actions that might be taken to achieve it are less obvious. This paper presents details of the Safe System approach, including the road safety context in Australia, and details of the Safe System approach as adopted. It also summarises current thinking in Australia on specific aspects of this approach, including speed management within a Safe System context; the role of infrastructure in delivering Safe System outcomes, and the role of road users in this system. Each of these issues is discussed based on recent Australian experience.

Introduction

Australia has made good progress in reducing deaths and injury on the road in the last few decades. As shown in Figure 1 (Cairney, 2006), deaths per 100,000 population have more than halved since the mid 1970’s. They have moved from being well above the OECD median to a point below.

Source: Cairney, 2006
Although this indicates a marked improvement in safety, the rate of improvement has decreased in recent years. More recent figures from the Australian Department of Infrastructure (2009) show that there has been a plateau in deaths per 100,000 population since 2004, and that rates are now again similar to the OECD median.

Source: Department of Infrastructure, 2009

The current ‘cost’ to society from road crashes (of all severities) is estimated to be around $18 billion per year, or around 3% of GDP (Cairney, 2006).

Furthermore, Australia is currently unlikely to meet the targets set as part of the National Road Safety Strategy (for the period 2000 to 2010). Figure 3 clearly shows the divergence from reductions required to meet that target.

Source: Australian Transport Council, 2008
There is a recognition within Australia that more needs to be done to continue the downward trend in crashes.

**The Safe System approach**

A change in approach to road safety was introduced as part of the 2005/06 national Action Plan (Australian Transport Council, 2004). This plan forms part of the national strategy, outlining progress and actions to be taken to improve safety in the following two year period. The Safe System approach outlined in this report has now been adopted by each jurisdiction within Australia.

The Australian Safe System approach is based primarily on the Swedish ‘Vision Zero’, and the Dutch ‘Sustainable Safety’ approaches. Vision Zero suggests that it is not acceptable for fatal or serious injuries to occur on the road system, and that account must be made of human tolerances when designing road infrastructure (see e.g. Tingvall, 1998). The Sustainable Safety approach (recently revised by Wegman and Aarts, 2006) is based on the following concepts:

- **Functionality**: roads should be differentiated by their function, with through roads which are designed for travel over long distances (typically at high speed, ideally on a motorway); distributor roads which serve districts, regions and suburbs; and local roads, which allow access to properties.
- **Homogeneity**: differences in vehicle speeds, direction of travel and mass on specific roads should be minimised.
- **Predictability**: the function and rules of a road should be clear to all road users. This approach has led to the development of the ‘self explaining road’ (e.g. Theeuwes & Godthelp, 1992; Schermers, 1999; SWOV, 2006)
- **Forgivingness**: roads and roadsides should be forgiving to road users in the event of an error.
- **State awareness**: road users should be able to assess their capability of handling the driving task.

Figure 4 presents the Safe System framework as presented in the 2009/10 national Action Plan (Australian Transport Council, 2008).
This framework is also presented in the recent OECD document titled *Towards zero: Ambitious Road Safety Targets and the Safe System Approach* (OECD, 2008).

Some of the key Safe System principles as outlined in the Australian Action Plan (Australian Transport Council, 2008) and the OECD (2008) document are as follow.

The approach recognises that humans as road users are fallible and will make mistakes. There are also limits to the kinetic energy exchange which humans can tolerate (e.g. during the rapid deceleration associated with a crash) before serious injury or death.
occurs. A key part of the Safe System approach requires that infrastructure be designed to take account of these errors and vulnerabilities so that road users are able to avoid serious injury or death on the road.

This represents a fundamental shift in thinking in how we try to address road safety. It accepts that road users will inevitably make errors, and that there is an obligation on those who manage the road network to provide a safe road and roadside environment. For almost all crashes there is likely to be some form of road improvement that could be made to reduce the likelihood of a fatal or serious injury crash occurring.

Speed management is core to the delivery of Safe System outcomes. A report by Fildes et al. (2005) summarises the biomechanical tolerances of humans for different crash types. Table 1 presents the findings from that work, showing the survivable impact speeds for various crash types. Human tolerances need to be considered in the setting of speed limits to ensure that in the event of a crash, no road users are killed or seriously injured.

<table>
<thead>
<tr>
<th>Crash type</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car/pedestrian</td>
<td>20-30 km/h</td>
</tr>
<tr>
<td>Car/motorcyclist</td>
<td>20-30 km/h</td>
</tr>
<tr>
<td>Car/tree or pole</td>
<td>30-40 km/h</td>
</tr>
<tr>
<td>Car/car (side impact)</td>
<td>50 km/h</td>
</tr>
<tr>
<td>Car/car (head-on)</td>
<td>70 km/h</td>
</tr>
</tbody>
</table>

Source: Fildes et al., 2005

The approach also recognises that road users can be made more alert and compliant through careful management of the entry and exit of vehicles and users to the system; by supporting users with education and information, by enforcement of road rules; and from a better understanding of road crashes and risks. However, as stated above, it is also recognised that no matter how alert and compliant road users are, they may still make errors, and therefore careful design is also required to avoid death and serious injury.

**Current progress in delivering a Safe System**

The Safe System now forms the basis of the national road safety strategy, and has also been adopted by individual jurisdictions when updating their strategies. Although the Safe System vision is clear within Australia, and there is general agreement about this, the approaches that might be taken to achieve this vision are less obvious. Good examples of Safe System design exist from around Australia and elsewhere in the world, but there is a need to better coordinate and communicate these lessons to all involved in delivering road safety. Advice is required regarding infrastructure options for achieving Safe System outcomes; on appropriate speed management strategies; and on ways to maximise the alertness and compliance of road users.

In order to help meet these objectives, a series of workshops have been held in Australia to discuss these issues. A national forum was recently held in Australia to examine
infrastructure options that might help achieve Safe System outcomes. The forum
involved around 40 senior road managers from Australia and New Zealand. Discussion
included current progress towards implementing Safe System principles, and options for
future implementation. Some of the outcomes from the event are discussed below, while
full details can be found in Turner et al (2009).

It was again recognised that the successful management of vehicle speeds is a critical
element of the Safe System approach. Recognition of the human tolerances to speeds in
different road environments provides useful direction for future infrastructure
improvement. As an example, it is recognised that above impact speeds of 50 km/h the
chances of surviving a side impact collision at an intersection begins to reduce
dramatically. This indicates the need to reduce speeds to 50 km/h in situations where
intersection conflicts are likely. This can be achieved through the installation of well
designed roundabouts, or the use of platforms at intersections. For situations where
higher speeds through intersections are required (i.e. on high speed major routes),
consideration should be given to grade separation or the banning of specific turn
movements and provision of acceleration and deceleration lanes.

Similarly, development of a clear functional road hierarchy for speed management
purposes is required for the implementation of Safe System infrastructure, and
particularly a system that provides a ‘self-explaining’ road for motorists. A rural and
urban hierarchy is required to identify roads that serve a ‘through traffic’ function, a
‘mixed’ function, and a ‘local access’ function. Speed limits, and the design of the road
environment need to be harmonised and consistent on each part of the hierarchy so as to
provide a self-explaining road for motorists.

A useful distinction was made between ‘Primary’ and ‘Supportive’ road safety
treatments. Primary treatments are those that directly provide a Safe System outcome
(i.e. minimise death and serious injury), for example by reducing impact forces to safe
levels or by separating different road users. Supportive treatments assist in delivering
safety improvements, but in an indirect manner (e.g. hazard warning signs may reduce
the incidence of crash occurrence, but should a crash occur, would not have an influence
on the severity outcome). Both are of use, but more use needs to be made of Primary
treatments. In addition efforts are required to develop new Primary treatments.
Continuing the intersection example provided above, there is a need to explore the use
of raised platforms at signalised intersections, or ways in which to slow vehicles on the
approach to intersections, perhaps through increased deflection and / or road narrowing.
Work is currently underway in Australia and elsewhere to explore these sorts of
possibilities.

Additional work is not only required to identify and implement Safe System
infrastructure for intersections, but also for other situations where fatal and serious
injuries are likely to occur. Of particular interest are measures to provide a forgiving
roadside environment (for example through removal or relocation of roadside hazards,
the use of crash friendly roadside features and barrier systems), measures that prevent
head-on crashes (particularly barrier systems), and measures that protect vulnerable
road users (including physical separation and slower speed environments).

The key recommendations from the forum were that:
1. Road safety targets and performance indicators need to relate to casualties, and particularly those with fatal or serious injury consequences.

2. Formal sharing of knowledge about Safe Systems between jurisdictions is required, including results from current demonstration projects.

3. There is a need for further development and greater use of Primary road safety treatments.

4. The public and policy makers need to be better informed about actual risks when using the road, and the need for lower speeds in certain road environments.

5. A functional hierarchy of urban and rural roads is required to assist in Safe System implementation. This needs to provide a clear distinction between different road classes in terms of their design, appearance and speed limits.

6. Improved knowledge is required about specific high risk locations on the road network. This should be based on a combination of crash history and risk assessment.

7. To deliver Safe System outcomes, road authorities need to improve linkages internally between various operating groups, with local councils and other external agencies, and with the community in general. Of particular importance is the need to improve the link between road safety departments, and those responsible for land use planning.

8. There is a need to assess the role of ITS in Safe System implementation. This assessment needs to consider infrastructure requirements to allow maximum benefits from these emerging technologies.

9. Road authorities need to take a strategic approach to establishing Safe System infrastructure into the future. The roundtable identified a suite of short to long term measures that will help in this approach. A major part of this strategic approach will be to ensure that staff are fully aware of Safe System principles and that they apply these in their practice.

It was identified that good progress is being made towards Safe System implementation in Australia, but there is a need to share good practice between jurisdictions more effectively. The report from this event (Turner et al 2009) is expected to form the basis for further discussions on the implementation of Safe System infrastructure, and to inform delivery strategies at local, state and national level.

A similar workshop was held to discuss speed management policy in light of the Safe System approach. This was held as part of an Austroads project on speed management (Austroads is the association of state and territory road authorities in Australia and New Zealand). A key aim of this workshop was to reconcile the gap between Safe System outcomes (a ‘must’ have) and mobility (a ‘should’ have).

A key outcome from this workshop was the recognition that it is often the case that drivers are not able to brake prior to the occurrence of a crash because there is no warning. For instance, a pedestrian may step out from behind a parked vehicle and be struck by a vehicle before any braking can occur. In this case, the impact speed will be equal to normal driving speed. Based on this assumption, the speeds presented above in Table 1 actually represent the desirable speed limits required in order to meet Safe System outcomes.
Through this Austroads project a Safe System Analysis method was developed to match the speed limit to the existing road infrastructure, or to recommend infrastructure improvements to retain a higher speed limit if this is the required function of the road. Further details of this process can be found in Jurewicz & Turner (2009).

A third workshop was held late in 2009, with the objective of discussing Safe System and how it applies to road user behaviour. Key points of discussion from this event included how we define an ‘alert and compliant’ road user. It was recognised that this is a complex issue, and that it is difficult to define these terms. Nevertheless, there was consensus that non-alert and non-compliant users should be catered for when designing a Safe System, although there is a limit to the extent that extreme speeds can be accommodated through vehicle and infrastructure design.

There was agreement that education programs are not effective in reducing death and injury directly, but that these are necessary for building a climate of opinion where vigorous action to improve safety can be pursued.

Other issues addressed were the identification of performance indicators for measuring progress towards Safe System outcomes. Examples of existing measures included the proportion of motorists who were above the legal blood/alcohol level or who were not wearing seatbelts. Other new indicators included a need to measure consumer purchasing patterns when buying vehicles, and consumer demand for information about safety.

The results of this workshop were still being assessed at the time this paper was being produced, but it is anticipated that a report will be released detailing the discussion in the near future.

Concluding remarks

Although great improvements have been made in road safety in Australia in the last few decades, there has been a slowing of improvements over recent years. The Safe System framework has been adopted as a way to make substantial future improvements to road safety in Australia. The vision appears clear, and appropriate steps to achieving Safe System outcomes are now being developed. The next challenge will be to ensure that the vision, as well as the steps required to achieve this are firmly embedded within policy at national, state and local level. This is a substantial task and will involve extensive education programs and monitoring. It will also involve a large infrastructure investment over a sustained period. However, given the annual cost of crashes in Australia, the cost of not taking appropriate action is likely to be even greater.

References


ORGANIZING FOR ROAD SAFETY IN BANGLADESH: SOME CHALLENGES AND OPPORTUNITIES

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Abstract

Bangladesh has a very serious and deteriorating road safety problem. While about 4000 deaths annually are reported to the police, it is estimated that over 10,000 deaths resulting from road crashes occur annually. Bangladesh with the lowest motorization level has the worst fatality rate (deaths/10,000 motor vehicles) of the region. The annual socio-economic costs represent around 2% of GDP. The most vulnerable road users - pedestrians, poor people and children suffer the most serious consequences of road traffic crashes. Road crashes are the leading cause of death for children aged between 10-14 years. The tragic, premature costly loss of life and permanent disability is hindering poverty reduction efforts particularly in rural areas. The number of reported traffic fatalities increased nearly 4 times over the last 26 years, 1982-2008. Road safety improvement efforts in Bangladesh however seriously suffer from several weaknesses and serious drawbacks. There is an urgent need to accelerate implementation of problem specific countermeasures, policies and conduct of good practice based on efforts of enhanced understanding, scientific analysis, monitoring and research. Effective road safety management across government needs to be established urgently and on a sustainable basis. Creating an effective organization dedicated to ownership and initiating and coordinating road safety activities is fundamentally important. All sectors will need to be motivated and engaged by activating lead agencies with a mandate of implementing very specific and explicit actions and strategies towards delivery of agreed visions, goals and targets. There is an urgent need to plan, design and implement an effective and sustainable institutional structure to address road safety challenges. In this paper an attempt has been made to discuss these aspects of road safety organizational arrangements. Some of the issues, challenges and opportunities in road safety management, institutional arrangements and the development of professional capability, knowledge and expertise through imparting training and sharing experience are also discussed in the paper.
1. INTRODUCTION

Bangladesh is a country in South Asia and is a very densely populated country with about 150 million inhabitants living in an area of 147,570 sq. km. i.e. around 1000 inhabitants live per sq. km. Road accidents are increasing alarmingly taking heavy toll of human lives. Personal injuries and property damages are common daily phenomenon. The road safety situation in Bangladesh is serious and deteriorating. While about 4000 deaths annually are reported to the police, it is estimated that over 10,000 deaths resulting from road crashes occur annually. Road safety improvement efforts in Bangladesh however seriously suffer from several weaknesses and serious drawbacks. With the current state of efforts and initiatives, it appears most unlikely to bring about any substantial safety improvements in Bangladesh. Road traffic accidents and fatalities cannot be expected to decrease rapidly and substantially unless focused and continuous efforts with scientific base are put in place with a sense of urgency. In particular there is an urgent need to accelerate implementation of problem specific countermeasures, policies and conduct of good practice based on efforts of enhanced understanding, scientific analysis, monitoring and research. Effective road safety management across government needs to be established urgently and on a sustainable basis.

In this paper an attempt has been made to highlight the road safety issues and priorities in Bangladesh with particular emphasis on shortcomings of organizational and institutional aspects. Some of the strengths, challenges and opportunities in road safety management, institutional arrangements and the development of technical capability, knowledge and expertise through international cooperation and sharing are also discussed in the paper.

2. ROAD SAFETY OVERVIEW IN BANGLADESH

Striking Characteristics

There were at least 3765 reported fatalities and 3284 injuries in 4427 accidents in Bangladesh in 2008. It is estimated that the actual fatalities could well be at least 12,000 each year and many more sustain disabling injuries. In economic terms, road accidents in Bangladesh costing community in the order of staggering US $ 1000 million, nearly 2 percent of GDP. The number of fatalities has been increasing from 1009 in 1982 to almost 3765 in 2008, nearly 4 times in 26 years period showing an increasing trend in recent years. The statistics revealed that Bangladesh has one of the highest fatality rates internationally in road accidents, over 100 deaths per 10,000 motor vehicles.

About 70 percent of road accident fatalities occurred in rural areas including rural sections of national highways. Also it has been observed from the studies that up to 62 percent of urban road accident deaths are pedestrians alone and in Dhaka city, they represented nearly 70 percent. Almost 80 percent of fatalities are vulnerable road users e.g. pedestrians, bicyclists and motorcyclists. Pedestrian-vehicle conflicts are clearly the greatest problem with significant involvement of trucks and buses. The road traffic injury is one of the major causes of mortality, morbidity and disability in Bangladesh. About one-fifth of injury related hospital admissions are due to road traffic accidents. Children are highly vulnerable in the traffic situation compared with
many other countries of the world. Road traffic crashes are the leading cause of death for children aged between 10-14 years. Some further more frequently occurring features of accidents are (Hoque and Mahmud 2009):

- Of the total reported accidents nearly 50 percent occurred on national and regional highways.
- The severity of accident outcomes on highways is often devastating with a result of involving many fatalities and injuries, up to 60 deaths and 150 injuries on the spot.
- Accidents and fatalities on national highways are characterized as clustering on selected sections, identified as Hazardous Road Locations (HRLs), nearly 40 percent of accidents concentrated on around 2 percent of the highway network, demonstrating that accidents are amenable to site specific treatments.
- Accident type analysis showed ‘hit pedestrian’ as the dominant accident type both in urban and rural areas, 45 percent involvement in fatal accidents. Other common accident types are: rear end collision (16.5%), head on collision (13.2%) and overturning (9.3%).
- Heavy vehicles such as trucks and buses including minibuses are major contributors to road accidents (bus/minibus 33%, trucks 27%) and in fatal accidents their shares are 35 percent and 29 percent respectively.
- About 2.5 percent of reported accidents occurred on bridges and culverts

Trends and Factors

As indicated earlier, the current national statistics reveals that road traffic accidents in Bangladesh have been on the rise in the recent years (see Table 1) and are forecasted to aggravate further unless urgent action is taken. The trends for annual number of fatalities (reported and estimated) for the last four decades are shown in Figure 1 (Ahsan 2009). Significant under reporting of deaths is of particular note which require which needs to be addressed for determining the actual societal and humanitarian impacts of road traffic accidents. In Bangladesh, motorized traffic is growing very rapidly (see Figure 2), around 400 new motorized vehicles are coming on to roads everyday. Over the next decade the motorized traffic is expected to be double which will exacerbate this challenging situation further unless the problem is duly and urgently addressed (Howard and Breen, 2008). It is noted that the growth of motorized two wheelers is very marked which emerges as a serious safety threat as well.

Table 1: Road Traffic Accidents in Bangladesh in the Recent Years

<table>
<thead>
<tr>
<th>Year</th>
<th>Accidents</th>
<th>Fatalities</th>
<th>Injuries</th>
<th>Casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>3917</td>
<td>2968</td>
<td>2752</td>
<td>5720</td>
</tr>
<tr>
<td>2005</td>
<td>4949</td>
<td>3187</td>
<td>2754</td>
<td>5941</td>
</tr>
<tr>
<td>2006</td>
<td>3794</td>
<td>3193</td>
<td>2409</td>
<td>5602</td>
</tr>
<tr>
<td>2007</td>
<td>4869</td>
<td>3749</td>
<td>3273</td>
<td>7022</td>
</tr>
<tr>
<td>2008</td>
<td>4427</td>
<td>3765</td>
<td>3284</td>
<td>7049</td>
</tr>
</tbody>
</table>
Figure 1: The trends for annual road fatalities (reported and estimated) for the last four decades

Figure 2: Registered motorized vehicles in Bangladesh (Source: BRTA, 2009)

The principal contributing factors to accidents are adverse roadway and roadside environment, poor detailed design of junctions and road sections, excessive speeding, overloading, dangerous overtaking, reckless driving, carelessness of road users, failure to obey mandatory traffic regulations, variety of vehicle characteristics and defects in vehicles and conflicting use of roads. The road environmental factors are particularly prevalent (typical road safety hazards are shown in Figure 3). Other issues of concern are: Under-reporting accidents; Defective and road unworthy motor vehicles; Drivers in competency; Road engineering and environmental deficiencies; Inadequacy in police inspection and law enforcement; Poor road user behaviour and safety education; Institutional weakness.
3. ORGANIZING ROAD SAFETY IN BANGLADESH

Some Issues and Challenges

Road safety improvement efforts in Bangladesh seriously suffer from several serious drawbacks and indeed represent significant issues which need to be addressed. These are lack of strong professional safety agency with adequate executive powers and responsibilities; fragmentation of responsibilities between agencies and insufficient inter-agency coordination; low level of staffing and lack of professional capacity; lack of trained traffic police for effective enforcement and traffic regulations; absence and inadequate dissemination of road safety research, and too few resources and funding directed towards tackling the safety problem etc.

With the current state of efforts and initiatives, it appears most unlikely to bring about any noticeable safety improvements. Road traffic accidents and fatalities cannot be expected to decrease rapidly and substantially unless focused and continuous efforts with scientific based are put in place with a sense of urgency. In particular there is a urgent need to accelerate implementation of problem specific countermeasures, policies and conduct of good practice based on efforts of enhanced understanding, scientific analysis, monitoring and research.

In the face of the above facts, a road safety workshop was held in November 2007 organized by the Accident Research Centre of the Bangladesh University of Engineering and Technology and the Roads and Highways Department (RHD) supported by the World Bank. It brought together key multisectoral road safety stakeholders in Bangladesh and World Bank representatives under the theme ‘Road Safety in Bangladesh: Constraints and Way Forward The workshop has emphasized that the significance of the road safety problem needs to be seriously recognized and addressed by the policymakers and officials and concluded that (Howard and Breen, 2008):

*It is time for action:* There is multi-sectoral professional concern about the seriousness of the problem and the urgent need for effective approaches. No lead agency has yet been appointed; stakeholder working partnerships have yet to be established and funding has not been allocated to allow the implementation of the road safety action plan which has been prepared and revised several times.

*A holistic approach to road safety is necessary:* Road safety intervention needs to be system-wide and needs to cover all the strategies: managing exposure to risk, crash
prevention, crash protection and post impact care. The road safety problem is man-
made, amenable to rational analysis, needing locally tailored evidence-based system-
wide intervention as well as improved institutional arrangements based on sound
management principles.

**Road safety is a shared responsibility:** Road safety is a multi-disciplinary issue and
the concern of government at national, regional and local levels, civil society and
business. Several key governmental sectors need to be involved – transport, justice
and police, health. Effective multi-sectoral effort needs to be well orchestrated by a
lead agency on a first amongst equals basis.

**Institutional arrangements form the foundation of the road safety management
system:** Seven key institutional management functions of the World Bank road safety
management system (Bliss and Breen 2009) were discussed: results focus,
coordination, funding, legislation, promotion, funding, monitoring and evaluation and
research and development and knowledge transfer.

**A 2nd Generation project supported by the World Bank and the Government of the
Republic of Bangladesh is needed:** A large-scale multi-sectoral demonstration 2nd
Generation Road Safety Project targeting a single high risk and high crash density
road corridor is seen most efficient and effective way to achieve road safety targets in
Bangladesh. It would aim to accelerate the transfer of road safety knowledge to
project participants; strengthen the capacity of participating agencies, industries and
community groups and achieve quick proven results benchmark measures to allow a
national roll-out programme.

**It would be useful for a safety management capacity review to be carried out:** A
review of current country capacity across the three dimensions of the road safety
management system; institutional arrangements, interventions and results could
usefully be carried out. This could lead to plan, design and implement an effective and
sustainable institutional structure to deliver road safety initiatives.

**Funding and Resource Allocation:** Budget constraints a major issue. The absence of
funding presents a formidable barrier to progress. The source, amount and
programming of required funding for safety improvements are also key challenges
that need to be addressed.

**Some Strategies and Opportunities**

There are encouraging signs and has been some progress with road safety
organizations, establishment of accident research institute, highway traffic patrol and
preparation of strategic road safety action plans of the National Road Safety Council
(NRSC). The latest version of the action plan identifies listing of various actions and
implementing agencies. Following the road safety workshop in 2007 on the
constraints and way forward, a road safety capacity review sponsored by the World
Bank was conducted - a vital step forward indeed.

The above capacity review now calls for a positive strategy to be adopted for
instituting structured road safety management organization to improve road safety
with serious commitment from officials, policymakers and the public. The strategy
should outline the policy, the means and resources needed to face this serious problem and set targets to achieve during set period of time. Lessons should be learned from the road safety experience in other successful countries such as Australia, New Zealand, Sweden and Malaysia. In view of the above facts, some specific strategic approaches and actions are outlined in the following sections.

**Setting up Institutional Structure for Road Safety:** The management review was carried in accordance with the guidelines set out in the World Bank’s Global Road Safety Facility study (Bliss and Breen, 2009). Figure 4 illustrates the key steps and integrated elements of the road safety management system. Essentially it encompasses the management system with three levels: *institutional management functions, interventions and results*. The system emphasizes on implementing a systematic, sustained and accountable focus and response to govern road safety results in a country and in particular places importance of the vital role of lead agency. Further detailed aspects of the recommended road safety management system can be seen in Bliss and Breen, 2009. Central theme of this integrated institutional management function is to learn from experience and experiment (e.g. through implementing a pilot demonstration road safety project). This process of learning by doing is critically important for Bangladesh where there is very little safety expertise available to deal with the safety issues holistically.

![Figure 4: Key steps and integrated elements of the road safety management system (Bliss and Breen, 2009).](image)

Therefore, the framework for integrated road safety management system and its requirements as set out above deserves serious consideration for the ownership and management of road safety in Bangladesh. This should take place with the ownership and support of the government and in partnership with key stakeholders. Essentially the management function has to be considered under the care and directives of the
highest level of the government (e.g. under the Prime Minister or Head of the government) securing adequate funding.

Importantly, one fundamental step to be taken by the government therefore is to create an organization dedicated to initiating and coordinating road safety activities as well as by activating lead agencies with a mandate of implementing very specific and explicit actions and strategies having requisite funding and resources. In particular efforts should be strengthened on the following institutional management aspects:

- Making road safety a policy priority, setting up of quantitative goals, objectives and targets (e.g. reductions in deaths and serious injuries, reductions of pedestrians and child deaths);
- Designating/creating a single central agency with the authority to address road safety for the oversight and encouragement of the institutional management function; A new road safety department needs to be established;
- Activating lead agencies in relevant sectors with clear roles and responsibilities, appropriate authority, co-ordination and resource availability and to monitor and evaluate improvements;
- Changes in road safety strategies approaches must be brought about to more towards 'rational' style road safety actions based on fact-based knowledge, science and technology and in particular should invoke the "safe system" approach and principles.

Training of Professionals and Researchers: The 'rational' delivery of road safety programs through structured management organizations essentially requires specialized group of people and qualified professionals sufficiently trained in fact based road safety knowledge in various sectors and disciplines. Indeed, training requires knowledge of fact which is the creation of researchers. Therefore, researchers also need to be trained (Hauer 2005). Clearly this strategy of developing a competent workforce (professionals, researchers and technicians) is fundamentally important for countries like Bangladesh to make a real difference in the way how road safety initiatives are undertaken and in achieving much needed safety improvements.

In summary, it can be reiterated that the lack of serious commitment and political will and the absence of institutional ownership to take road safety as social responsibility are major barriers to implementing road safety programs in Bangladesh. From the world experience, it is now abundantly clear that the whole problem of road safety is within our control and that it is capable of being addressed in a very structured way with a scientific base. The strategy for addressing the problem holistically and urgently requires lead agency, new institutional arrangements, institutional and professional capacity, research and funding. The existence of accident and injury research institutes, local professional expertise, growing awareness among professionals and promoting active and collaborative support of key international and national donors are considerable opportunities to make progress. The above actions for developing national capacity are overwhelmingly important in delivering the local plan of actions in commensurate with the global call for the decade of actions.
4. CONCLUDING REMARKS

This paper has provided a brief overview of the road safety problems in Bangladesh. It argued that with the current state of efforts and initiatives, it appears most unlikely to bring about any noticeable safety improvements. Road traffic accidents and fatalities cannot be expected to decrease rapidly and substantially unless focused and continuous efforts with scientific base and structured and effective institutional ownership and arrangements are put in place with a sense of urgency. One fundamental step to be taken by the government is to create an organization dedicated to initiating and coordinating road safety activities as well as by activating lead agencies with a mandate of implementing very specific and explicit actions and strategies. In addition, some challenges and opportunities for designing and instituting road safety management organizations and building professional capacity are discussed.

5. REFERENCES


2. Bangladesh Road Transport Authority (BRTA) (2009), "Statistics on Registered Motorized Vehicles in Bangladesh", Personal communications


ABSTRACT
A 3-step procedure to assess road safety conditions is developed and applied to Egypt as a prototype example. Assessing road safety culture represents the first step in judging the road safety situation in a developing country. This can be represented through 14 aspects, namely: Political, Institutional, Safety Lobbying, Safety Research, Engineering, Accident Management System, Evaluation, Behavior, Legislation, Enforcement and Standards, Emergency, Education, Mass Media, Coordination and Cooperation. These were applied to describe and assess the road safety condition in Egypt. This is followed by comparing severity indicators among several countries in an effort to determine the road safety position in Egypt. The third step involved compiling and analyzing accident records for five main rural roads in Egypt. Most of the highly contributing causes are driver related including loss of control of driving wheel, over speed, misjudgment of traffic gap, sudden slowing/stoppage. Two other vehicle related causes are frequently mentioned, i.e. tire burst and vehicle turnover/turn off the road. The paper concludes by developing an integrated road safety programme composed of 16 fields of actions namely: institutional, land use planning and management, travel demand management, road infrastructure improvement, legislation, traffic-related, accident-related, vehicle-related, driver-related, traffic police-related, enforcement, educational, mass-media, community related, health-related and research-related measures. These should complement each other and work together in a supportive way to tackle the particular road safety problem.

1 INTRODUCTION
The road environment in many developing countries is known to be relatively unsafe, and uncomfortable. Several factors contribute to this situation; some are related to the unsatisfactory design and layout of roads, sidewalks and road furniture. Other problems are related to the poor condition of vehicles that travel on the roads. Most importantly, there is a general trend among drivers and pedestrians of non-compliance with traffic rules and regulations. The situation is further aggravated by a deficiency in traffic legislation and a lack of serious enforcement.

World Health Organisation (WHO) ranks road accidents as the 9th leading cause of mortality and disease. It forecasted that by the year 2020, if programmes are not implemented, road crashes will move up to third place of leading causes of death and disability facing the world community, see WHO, 2004. Studies carried out by the Overseas Unit of the British Transport Research Laboratory (TRL), the French National Institute for Transport and Safety Research (INRETS), and WHO have demonstrated that road accidents in the Third World:
• are a major cause of death and injury, for example they account for almost 10 percent of deaths reported in the 5 - 44 year age group.
• are a considerable waste of scarce resources with accidents typically costing at least 1% to 2% of countries’ GNP per annum, in addition to the substantial pain, grief and suffering.
• represent a serious problem in terms of fatality rates with rates at least an order of magnitude higher than those in industrialised countries.
In this context, it becomes inevitable that developing countries ought to pursue all possible means to prevent road accidents and relieve their severity, hence achieving acceptable road safety levels. Such prevention has to be based on a proper diagnostic assessment of the road safety situation. Towards this end this paper starts by developing a conceptualization of the road safety pyramid, its components and affecting factors. The road safety pyramid is represented by five components, namely traffic exposure; traffic safety culture, dangerous incidents; accident, severity and damage risk rates as well as accident and casualty based severity rates. In addition, the pyramid shows a categorization of the main factors contributing to the occurrence of road accidents.

The paper develops a three-step procedure to assess road safety conditions. In the first step, a set of generic criteria that can be used to describe and compare the road safety culture is proposed. The second step involves a review, detailed categorisation and computation of the main road safety indicators. Finally, the third step for assessing road safety is concerned with compiling and analysing accident records and identifying accident causes. The developed procedure is applied for Egypt as a prototype example representing developing countries. More than 40 criteria are identified and applied in an attempt to semantically assess the road safety culture in Egypt. Deaths per million vehicle kilometers are obtained for Egypt, three other Arab countries and 6 of the G-7 countries. These were compared in an effort to determine the road safety position of Egypt. Accident records collected in 1998 for five main rural roads in Egypt are compiled and analysed to recognise accident causes. More than 26 causes are identified. These are categorized under six main categories, namely driver related, pedestrian related, vehicle related, road related, environment-related causes and other causes.

Furthermore, the paper concludes by developing an integrated road safety program composed of 16 fields of actions. Each of these contains a number of recommended policies, measures and actions targeted to improve road safety not only in Egypt but also in other developing countries. These are also categorized in accordance with the concerned authority/agency responsible for implementation. The paper concludes by suggesting further road safety research that is needed in developing countries.

2 DEVELOPING ROAD SAFETY PYRAMID
Road safety can be conceptualised as a pyramid composed of five main components at different levels, see figure 1. Towards the base of the pyramid is traffic exposure representing the extent (intensity) and form (nature) of how road users are exposed to traffic. Several traffic related data can be used to represent the extent of traffic exposure. The two most widely used in road safety studies and international comparisons are Annual Average Daily Traffic (AADT) as well as Annual Average Vehicle Kilometers (AAVK). On the other hand, the form of traffic exposure can be defined as the way road users are exposed to the traffic environment. However, due to difficulties in measurement and data collection, the notion of form and nature of traffic exposure is not usually taken into account in most road safety studies.

The second level of the road safety pyramid represents what could be referred to as the prevailing road safety culture. In this research, road safety culture is defined as the cultural environment in which road safety issues are dealt with as well as the level of awareness of the various stakeholders involved with road safety issues. The third level of the road safety pyramid represents the extent and nature of occurring dangerous incidents, see Tight et al., 1998. This can be expressed in terms of number and severity of incidents such as near misses, conflict points, evasive maneuvering, etc. The fourth level of the road safety pyramid represents traffic risk rates. These are indicators relating frequency of accidents, casualties, fatalities,
injuries as well as damages to various exposure measures. Such indicators when computed are representative of probability of accident occurrence. Finally, towards the top of the traffic safety pyramid are what can be referred to as severity rates. These indicators are meant to express probability of an accident resulting into fatalities or a degree of injury or the probability of an accident casualty being a fatality or an injury. These are computed by relating the number of fatalities or injuries either to the number of accidents or to the number of accident casualties.

In developing the road safety pyramid, factors contributing to the occurrence of traffic accidents were identified. These can be grouped into four main categories. Such categorization is based on the nature and time frame of the effect of these factors (causes) on the five components describing road safety. The identified causes include:

(a) Deeply rooted causes of accidents, casualties and damages. These are causes related to the pre-effect of unsafe land use planning and management on traffic exposure extent and form.
(b) Root causes of accidents, casualties and damages. These are related to the pre-effect of unsafe transportation planning and management on traffic exposure extent and form.
(c) Direct causes of accidents, casualties and damages. These can be further categorized into four groupings, namely road related, user related, traffic management related and vehicle related. These four factors are known to be directly contributing to the occurrence of both dangerous incidents as well as actual road accidents with varying severity.
(d) Post causes of accidents, casualties and damages. These are related to factors occurring after an accident took place. Such factors include the effect of accident site management, ambulance and emergency management, medical treatment and trauma management. Such factors may reduce or increase the possibility of a slightly injured victim becoming severely injured or a severely injured victim becoming a fatality.

Figure 1: Conceptualisation of road safety pyramid: Components and affecting factors
3 ASSESSMENT OF ROAD SAFETY CULTURE

According to Vasconcellos, 1996, unsafe traffic conditions in developing countries have to be analysed in the context of physical, political, technical and enforcement environments. In this research, the notion of road safety culture is introduced. Assessing road safety culture represents the first step in judging the road safety situation in a developing country. Road safety culture can be represented through 14 aspects, namely:

- Political
- Institutional
- Safety Lobbying
- Safety Research
- Engineering
- Accident Management System
- Emergency
- Evaluation
- Behavior
- Legislation
- Enforcement and Standards
- Education
- Media
- Coordination and Cooperation

These aspects are further disaggregated into 40 suggested criterion. The applicability of using these aspects and their related criteria in assessing road safety culture is demonstrated, in Table 1, taking Egypt as a prototype case study. The table shows the semantic description of status of each of these criteria in Egypt.

Table 1: Semantic assessment of road safety culture (environment & awareness) in Egypt

<table>
<thead>
<tr>
<th>Aspects of Road Safety Culture</th>
<th>Assessment Criteria</th>
<th>Semantic Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political</td>
<td>Awareness of decision-makers and politicians of road safety</td>
<td>Fully aware, medium priority, relatively limited intervention.</td>
</tr>
<tr>
<td></td>
<td>Goals, policies, targets, objectives on road safety</td>
<td>Almost not existing.</td>
</tr>
<tr>
<td>Institutional</td>
<td>National road safety body</td>
<td>An institute for Traffic Accident Research was established in 1994 as part of Ministry of Interior traffic police. However limited funding, resources and political support are hindering its operation.</td>
</tr>
<tr>
<td>Safety Lobbying</td>
<td>Road safety lobbying</td>
<td>Exist but uncoordinated</td>
</tr>
<tr>
<td></td>
<td>Involvement of international road safety research organizations</td>
<td>TRRL (Overseas Unit) involved in 1987 through 1990.</td>
</tr>
<tr>
<td></td>
<td>Non government organizations concerned with road safety</td>
<td>Egyptian Society for Road Safety (limited educative &amp; informative role)</td>
</tr>
<tr>
<td>Safety Research</td>
<td>National road safety research project</td>
<td>1. 87-90 study, Sponsored by Egyptian Academy of Science Research &amp; Technology (EASRT) in conjunction with UK Transport Research Laboratory &amp; Egyptian Academics. 2. 96-99 study, Sponsored by EASRT with Egyptian Traffic Police Department &amp; Egyptian Academics.</td>
</tr>
<tr>
<td></td>
<td>Other road safety research include studies on road &amp; vehicle conditions, road-user behavior, traffic characteristics, legislation/enforcement</td>
<td>Limited individual, uncoordinated &amp; unsponsored research at concerned university departments &amp; specialized institutes.</td>
</tr>
<tr>
<td></td>
<td>Road safety experts/academics</td>
<td>Few transport/traffic academic experts are present in Egypt with some specialised in traffic safety</td>
</tr>
<tr>
<td>Engineering</td>
<td>Locally developed highway standards</td>
<td>First Egyptian Highway Code was issued in 2000 including safety and quality aspects.</td>
</tr>
<tr>
<td>Accident Management System</td>
<td>Accident reporting system</td>
<td>First EASRT study produced 4 detailed &amp; comprehensive booklets (accident, technical, medical, economic). These were used during study period. Then detailed recording stopped between 90 to 96. Another simplified form was designed in 1996 by second EASRT study. Traffic police is currently adopting the new form.</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Quality &amp; quantity of completed forms</td>
<td>Lot of underreporting exists especially for damage only accidents. Most information in the forms is completed. However, it is usually the case that this is done by traffic police officers in their offices, sometime hours after accident occurrence.</td>
<td></td>
</tr>
<tr>
<td>Maintenance of accidents data-base</td>
<td>Started in 1997 by the Traffic Police department as part of the second research project using a specially designed Oracle based software.</td>
<td></td>
</tr>
<tr>
<td>Dissemination of accident data</td>
<td>Very tight and controlled dissemination.</td>
<td></td>
</tr>
<tr>
<td>Accident analysis system</td>
<td>Started in 1997 by Traffic Police department as part of second research project using a specially designed reporting system based on Oracle.</td>
<td></td>
</tr>
<tr>
<td>Identification of accidents locations</td>
<td>Black spot identification carried out by traffic police</td>
<td></td>
</tr>
<tr>
<td>Identification of victims patterns</td>
<td>Can be done but currently limited attention.</td>
<td></td>
</tr>
<tr>
<td>Diagnosis of direct accidents causes</td>
<td>Sometimes undertaken.</td>
<td></td>
</tr>
<tr>
<td>Diagnosis of root accidents causes</td>
<td>Does not exist.</td>
<td></td>
</tr>
<tr>
<td>Identification of potential countermeasures</td>
<td>Exist but limited.</td>
<td></td>
</tr>
<tr>
<td>Costing of safety countermeasures</td>
<td>Exist but limited.</td>
<td></td>
</tr>
<tr>
<td>Valuation of traffic accidents</td>
<td>First national study included a detailed collection of accident costs and accident valuation based mainly on lost gross output and a value added to account for intangibles.</td>
<td></td>
</tr>
<tr>
<td>Pre-evaluation of safety countermeasures</td>
<td>Rarely undertaken.</td>
<td></td>
</tr>
<tr>
<td>Post-evaluation of safety countermeasures</td>
<td>Exist but limited.</td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>Inclusion of accident reductions as benefits in highway appraisals Not taken into account.</td>
<td></td>
</tr>
<tr>
<td>Behavior</td>
<td>Road users’ respect of traffic rules Limited.</td>
<td></td>
</tr>
<tr>
<td>Legislation</td>
<td>Traffic legislation Not strict enough. An improvement was recently passed including enforcement of seat belts and helmets. Other improvements are still needed.</td>
<td></td>
</tr>
<tr>
<td>Enforcement &amp; Standards</td>
<td>Vehicle inspection All vehicles have to be inspected. However, limited safety evaluation criteria are included &amp; corruption exists.</td>
<td></td>
</tr>
<tr>
<td>Driving test pass rate</td>
<td>High but recently more stringent.</td>
<td></td>
</tr>
<tr>
<td>Driving test theoretical part (Signs)</td>
<td>Well observed.</td>
<td></td>
</tr>
<tr>
<td>Driving test theoretical part (Highway Code)</td>
<td>Relatively neglected.</td>
<td></td>
</tr>
<tr>
<td>Driving test practical part</td>
<td>Involves limited maneuvering on a test area.</td>
<td></td>
</tr>
<tr>
<td>Special training for traffic police</td>
<td>Exist.</td>
<td></td>
</tr>
<tr>
<td>Emergency</td>
<td>High speed emergency service Relatively good. On road medical centers and emergency hospitals exist. One hospital being established with helicopter rescue service (private &amp; government efforts).</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>Separate road safety syllabus for school education Some road safety related children books were developed. However, still no formal road safety education at schools.</td>
<td></td>
</tr>
<tr>
<td>Children traffic parks</td>
<td>Exist as a component of a limited number of private recreation parks.</td>
<td></td>
</tr>
<tr>
<td>Mass-media</td>
<td>Radio and television programs on road safety Exist but limited.</td>
<td></td>
</tr>
<tr>
<td>Road safety posters and leaflets</td>
<td>Almost do not exist.</td>
<td></td>
</tr>
<tr>
<td>Coordination &amp; Cooperation</td>
<td>Liaison between traffic police and road engineers Exist but not coordinated.</td>
<td></td>
</tr>
<tr>
<td>Road safety week</td>
<td>Sometimes, not regular.</td>
<td></td>
</tr>
</tbody>
</table>
4 ROAD SAFETY INDICATORS: PURPOSE AND CLASSIFICATION

Absolute numbers of traffic accidents, casualties, fatalities and damages do not represent indicative figures to be used for assessment and comparison of road safety. The most meaningful indicators are relative values. These are known as road safety indicators. Computing road safety indicators represents the second step in the assessment of the road safety situation in a developing country. Road safety indicators serve several purposes, namely:

- Identification of safety problems and their intensities
- Determination of road safety levels
- Comparison of road safety levels
- Design of effective accidents’ countermeasures
- Evaluation of accident countermeasures

The literature also shows that there are several types of exposure measures that can be used in the computation of road safety indicators and hence in the evaluation of road safety, see Chang, 1982. As shown in figure 2, seven groups of exposure statistics are suggested to be utilized in the computation of road safety indicators, namely:

(a) National based exposure measures
(b) Traffic based exposure measures
(c) User based exposure measures
(d) Distance based exposure measures
(e) Time based exposure measures
(f) User-distance based exposure measures
(g) User-time based exposure measures

Definitions and mathematical formulations for each of these road safety indicators are presented below.

**Static exposure indicators**: These represent degrees of static exposure to accidents. This is done by computing the relativity of static national based exposure statistics, such as area, population, registered vehicles, licensed drivers and road kilometers, to each other as follows:

| Static exposure indicator (Type 1) = Licensed drivers/Population |
| Static exposure indicator (Type 2) = Registered vehicles/Licensed drivers |
| Static exposure indicator (Type 3) = Kilometres of road/Land area |
| Static exposure indicator (Type 4) = Kilometres of road/Population |
| Static exposure indicator (Type 5) = Kilometres of road/Licensed drivers |
| Static exposure indicator (Type 6) = Registered vehicles/Kilometres of road |

**Dynamic exposure indicators**: These represent degrees of dynamic exposure to accidents. This is done by computing the relativity of dynamic based exposure statistics; such as traffic, number of users, travelled distance, journey times, user-distance and user-time; to static national based exposure statistics as follows:

| Dynamic exposure indicators (Type 1) = Traffic exposure statistics/National exposure statistics |
| Dynamic exposure indicator (Type 2) = User exposure statistics/National exposure statistics |
| Dynamic exposure indicator (Type 3) = Distance exposure statistics/National exposure statistics |
| Dynamic exposure indicator (Type 4) = Time exposure statistics/National exposure statistics |
| Dynamic exposure indicator (Type 5) = User-Distance exposure statistics/National exposure statistics |
| Dynamic exposure indicator (Type 6) = User-Time exposure statistics/National exposure statistics |

**Accidents’ risk indicators**: These represent the number of accidents relative to selected exposure statistics. These are computed as follows:
Accidents’ risk indicators = Number of accidents/Exposure statistics

Severity risk indicators: These represent the numbers of casualties or fatalities or injuries relative to selected exposure statistics. These are computed as follows:

Severity risk indicators (Type 1) = Number of casualties/Exposure statistics
Severity risk indicators (Type 2) = Number of fatalities/Exposure statistics
Severity risk indicators (Type 3) = Number of severely injured/Exposure statistics
Severity risk indicators (Type 4) = Number of slightly injured/Exposure statistics

Damage risk indicators: These represent the number of damage only accidents relative to selected exposure statistics. These are computed as follows:

Damage risk indicators = Number of damage accidents/Exposure statistics

Accident based severity indicators: These represent the numbers of casualties or fatalities or injuries relative to the number of accidents. These are computed as follows:

Accident based severity indicator (Type 1) = Number of casualties/Number of accidents
Accident based severity indicator (Type 2) = Number of fatalities/Number of accidents
Accident based severity indicator (Type 3) = Number of severely injured/Number of accidents
Accident based severity indicator (Type 4) = Number of slightly injured/Number of accidents

Casualty based severity indicators: These represent the numbers of fatalities or injuries relative to the number of casualties. These are computed as follows:

Casualty based severity indicator (Type 1) = Number of fatalities/Number of casualties
Casualty based severity indicator (Type 2) = Number of severely injured/Number of casualties
Casualty based severity indicator (Type 3) = Number of slightly injured/Number of casualties

Figure 2: Types of Road Safety Indicators/Measures: Required Data & Basis for Computation
4.1 Fatalities per 100000 People
Currently the statistic most often used to compare road safety records around the world is the number of persons killed for every 100000 people, see IRF World Road Statistics 2009. In this section, an attempt is made to draw data from this recent publication in order to conduct an international comparison of road deaths per 100000 people among Egypt, some Arab Middle eastern countries, and some of the G-7 countries, see Table 2. The table demonstrates how this severity indicator can be used in the assessment of road safety in Egypt comparable to other countries.

The table shows that Egypt stands as having a significantly high rate of deaths per 100000 people than all of the selected G-7 countries. However, when compared to other Arab countries in the region Egypt stands to have the lower deaths per 100000 people. However, caution must be used in drawing absolute conclusions about relative road safety among the countries as this indicator does not relate accident deaths to a real exposure measure. A better statistic to compare road safety records around the world is the number of persons killed for every 100 million vehicles-kilometers. The difficulty of obtaining such indicator lies in the availability of correct data or computation of vehicle-kilometers. Still, the above comparison shows the worsening situation of road safety in Egypt.

Table 2: Deaths per 100000 People: An international comparison (Source IRF, 2009)

<table>
<thead>
<tr>
<th>Countries</th>
<th>Japan</th>
<th>France</th>
<th>Germany</th>
<th>Italy</th>
<th>UK</th>
<th>USA</th>
<th>Saudi Arabia</th>
<th>Egypt</th>
<th>UAE</th>
<th>Jordan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths per 100000 People</td>
<td>5.2</td>
<td>7.49</td>
<td>6.02</td>
<td>8.64</td>
<td>4.83</td>
<td>13.68</td>
<td>26.32</td>
<td>16.29</td>
<td>23.46</td>
<td>17.35</td>
</tr>
</tbody>
</table>

5 ANALYSIS OF ACCIDENT CAUSES FOR RURAL HIGHWAY NETWORK IN EGYPT
Analysis of accident causes represents the third step in the proposed assessment of the road safety situation in a country. In this section, an analysis of accident causes on the rural road network in Egypt is presented. Two accident investigation programs took place in Egypt. The first was initiated in the 1980's, when a national study funded by EASRT was conducted, see EASRT, 1991. In this study, accident and traffic behavior data were collected for five main rural roads in Egypt and three major districts in Greater Cairo. The study was undertaken by the Traffic Police Department in conjunction with Egyptian academics and cooperation of the UK Transport and Road Research Laboratory. The accident management system developed by this study was not fully pursued due mainly to lack of allocated resources and the sophistication and length of the data collection forms. The second program, which was also funded by EASRT, looked at developing an accident management system with an easy to use accident-reporting form. The developed system was applied for the collection, analysis and reporting of traffic accidents for 14 sections of roads representing eight major rural roads in Egypt. The traffic police department in conjunction with Egyptian academics undertook this study. Data collection spanned over the period 1997 to 1998 and is currently being maintained by the traffic police department in accordance with the developed system.

Analysis of causes of accidents for rural roads in Egypt is based on accident data collected in the second study for year 1998. The developed accident reporting form contains 27 causes of accidents see Table 3.
Table 3: Share of accidents’ causes for five main rural roads in Egypt (1998 Data)

<table>
<thead>
<tr>
<th>Accidents’ Causes</th>
<th>Five Considered Main Rural Roads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>User Related Causes (Driver)</strong></td>
<td></td>
</tr>
<tr>
<td>Loss of Control of Driving Wheel</td>
<td>378</td>
</tr>
<tr>
<td>Over Speed</td>
<td>174</td>
</tr>
<tr>
<td>Misjudgment of Traffic Gap</td>
<td>167</td>
</tr>
<tr>
<td>Sudden Slowing/Stoppage</td>
<td>110</td>
</tr>
<tr>
<td>Un-careful Lane Changing</td>
<td>48</td>
</tr>
<tr>
<td>Overtaking from the Right</td>
<td>37</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>914</td>
</tr>
<tr>
<td><strong>User Related Causes (Pedestrian)</strong></td>
<td></td>
</tr>
<tr>
<td>Misjudging Traffic Speed While Crossing</td>
<td>45</td>
</tr>
<tr>
<td>Standing/Walking on Road Shoulder</td>
<td>15</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>60</td>
</tr>
<tr>
<td><strong>Vehicle Related Causes</strong></td>
<td></td>
</tr>
<tr>
<td>Tire Burst &amp; Vehicle Turnover</td>
<td>204</td>
</tr>
<tr>
<td>Tire Burst and Vehicle Turn Off Road</td>
<td>71</td>
</tr>
<tr>
<td>Tire Separation</td>
<td>12</td>
</tr>
<tr>
<td>Brake Deficiency</td>
<td>11</td>
</tr>
<tr>
<td>Trailer Separation</td>
<td>7</td>
</tr>
<tr>
<td>Non-operable Vehicle lights</td>
<td>3</td>
</tr>
<tr>
<td>Reflective Mirrors Missing</td>
<td>2</td>
</tr>
<tr>
<td>Deficiency in Window Screens</td>
<td>1</td>
</tr>
<tr>
<td>Vehicle Overloaded</td>
<td>1</td>
</tr>
<tr>
<td>Load Length Beyond Permissible</td>
<td>0</td>
</tr>
<tr>
<td>Load Height Beyond Permissible</td>
<td>1</td>
</tr>
<tr>
<td>Load Falling (Trailer Connection Defect)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>315</td>
</tr>
<tr>
<td><strong>Road Related Causes</strong></td>
<td></td>
</tr>
<tr>
<td>U-Turns</td>
<td>38</td>
</tr>
<tr>
<td>Skidding Surface</td>
<td>4</td>
</tr>
<tr>
<td>Dangerous Curve/Gradient</td>
<td>4</td>
</tr>
<tr>
<td>Road Works</td>
<td>2</td>
</tr>
<tr>
<td>Poor Road Condition</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>49</td>
</tr>
<tr>
<td><strong>Environment Related Causes</strong></td>
<td></td>
</tr>
<tr>
<td>Bad Weather Conditions</td>
<td>41</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>41</td>
</tr>
<tr>
<td><strong>Other Causes</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>23</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1402</td>
</tr>
</tbody>
</table>

A traffic police at an accident site can mark one or more of these as causes for an accident. These are listed and categorized in Table 3 into six categories, namely: driver related causes (6 causes), pedestrian related causes (2 causes), vehicle related causes (12 causes), road related causes (5 causes), environment related causes (1 cause) and other causes. The frequency and contributing percentage of each of the considered accident causes is also shown in table 3. Most of the highly contributing causes are driver related. These include loss of control of driving wheel, over speed, misjudgment of traffic gap, sudden slowing/stoppage.

Two other causes related to the vehicle are frequently mentioned, i.e. tire burst and vehicle turnover or turn off the road. Together, these six causes contribute around 83% of accident causes on the five roads. In general, driver related causes contribute around 59% to 73%. This is followed by vehicle related causes contributing around 23%. Pedestrian related causes also
contribute around 4%, while road related causes contribute only 3.5%. Environment and other related causes are in the range of 3.5%.

6 AN INTEGRATED PACKAGE TO IMPROVE ROAD SAFETY IN EGYPT AND OTHER DEVELOPING COUNTRIES

Based on the previous analysis, review, conclusions, author’s experience and discussions with several experts and officials, the paper develops an integrated road safety program applicable for Egypt and other developing countries, see Table 4. Such program is composed of various policies, measures and actions targeted to improve road safety. These are categorized into 16 topical fields of action namely: institutional, land use planning and management, travel demand management, road infrastructure improvement, legislation, traffic-related, accident-related, vehicle-related, driver-related, traffic police-related, enforcement, educational, mass-media, community related, health-related and research-related measures. In addition, the table shows for each of the topical areas the concerned body, authority or agency that is thought to be most suitable to hold responsibility for implementation.

It is to be noted that these outlined policies and measures should not be treated separately. As a matter of fact, any package of road safety countermeasures should include measures from each of these fields of action. These should complement each other and work together in a supportive way so as to tackle the particular road safety problem. The table attempts to list the fields of action in a priority fashion where the starting phase should focus on developing the institutional framework complemented by research and legislation. This is then followed by planning, establishing strong enforcement, educating and communicating to the public.

Table 4: Integrated program to improve road safety in Egypt & other developing countries

<table>
<thead>
<tr>
<th>Field of Action</th>
<th>Policies, Measures &amp; Actions Targeted to Improve Road Safety in Egypt &amp; Other Developing Countries</th>
<th>Concerned Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional</td>
<td>• Establish a proper institutional framework to support and ensure continuity of implementation of road safety activities. This should have the necessary authority to enable it to work and coordinate all road safety efforts conducted by different ministries, authorities and organizations. This could take the form of a National Road Safety Council to cut across several government and nongovernmental bodies to advise government on policy formulation for road safety activities. Such council should have support at highest level in government and should also have a legal entity. &lt;br&gt; • Establish a Road Safety Unit to implement programmes pertaining to road safety. Such unit should draw expertise from various institutions in the country such as transport academics, traffic police, road safety experts, psychologists, doctors, educationist, social workers, etc. The unit should have provincial/district offices to provide in field backup.</td>
<td>Prime Minister Cabinet</td>
</tr>
<tr>
<td>Research-Related</td>
<td>• Special grants to conduct road safety research offered and consistency maintained. &lt;br&gt; • Organize national and international road safety conferences. &lt;br&gt; • Easy and accessible dissemination of accident data to all interested organizations/individuals that need to use data particularly for research. &lt;br&gt; • Conduct specialized research in transport &amp; traffic eng. as related to road safety. &lt;br&gt; • Organize training courses, seminars, and lectures for engineers, professionals and technicians in the areas of road safety. &lt;br&gt; • Establish research linkages and contacts with international road safety organisations and research centers. &lt;br&gt; • Develop and update specialised libraries through which access and dissemination of road safety research publications, information could be maintained.</td>
<td>Safety Research Institutes &amp; Universities</td>
</tr>
<tr>
<td>Legislation</td>
<td>• Issuing laws that grant traffic police more enforcement authority. &lt;br&gt; • Stringent penalties for violations should be adopted. Penalty package including warnings, penalty points, on the spot fines, off the spot fines, traffic driving license withdrawal, driving suspension, suspended imprisonment, driving license revoking</td>
<td>Legislative Bodies</td>
</tr>
<tr>
<td>Land Use Planning &amp; Management</td>
<td>Legislation penalising pedestrians for violating traffic rules and regulations, such as crossing carriageway at any location, should be issued.</td>
<td></td>
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<tr>
<td></td>
<td>Legislation to be developed that strictly and totally prohibits drinking and driving, driving with no seat belts or safety helmets.</td>
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<tr>
<td></td>
<td>Low speed limits should be established in urban areas especially in front of schools, and areas characterised by heavy pedestrian movements.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>In general, traffic laws to be repeatedly updated. New offenses to be clearly defined and stringent penalties to be specified.</td>
<td></td>
</tr>
</tbody>
</table>

| Enforcement | Ensure compatibility of land use types along main roads. |
|             | Land allocated for residential activities to be separated from main roads. |
|             | Activities attracting heavy goods vehicles to be located on main roads. |
|             | Adopt a hierarchical classification for road network functional of land use. |
|             | Relocation & resettlement of urban sprawls existing at cities periphery and especially those around start and end of intercity roads. |
|             | Consideration of road safety aspects in selecting locations for originating and ending points of intercity roads. |
|             | Land use plans that minimise the travelling distances, thus encouraging more pedestrian walking rather than vehicle traffic, should be considered. |
|             | Choosing safe locations for schools, and allocating substantial space for school playgrounds. School entrances to be at lightly trafficked side-roads. |

| Educational | A strong commitment towards road safety education & training at schools is needed. Road safety to be a separate, graded subject at all schools. |
|            | Developing teachers’ guidelines for instructing teachers on how to teach road safety for school children. |
|            | Construct children traffic parks to educate and train children of safe practices when dealing with the traffic environment. |

| Mass-Media | Promoting and raising society awareness of potential traffic hazards. Media campaigns to concentrate on disseminating knowledge to the public regarding safe use of road environment, as well as attempting to change unsafe traffic attitudes. |
|           | An annual traffic week or a monthly traffic day should be developed. This involves concentrated mass media campaigns on road safety aspects, press articles, exhibitions, competitions, posters, leaflets and pamphlets. |
|           | Television and radio interviews with officials responsible for road safety such as traffic police officers, academics, engineers, doctors, and teachers. |

| Travel Demand Management | Provision of public transport facilities that offer premium levels of service to encourage private-car users to switch to using public transport facilities. |
|                          | Different forms of car-pooling should be encouraged. |
|                          | Different forms of city traffic restraint to be practiced such as high parking fees, restricted parking areas, city entry tolls, staggered license plate entry. |

<p>| Road Infrastructure Improvement | Incorporating potential reductions in traffic accidents as benefits when conducting feasibility assessment of constructing new roads. |
|                                | Design of new roads to incorporate design safety criteria. |
|                                | Stringent monitoring and quality control during construction of new roads and maintenance of existing ones. |
|                                | Taking necessary safety precautions during road works. |
|                                | Alignments of new intercity roads selected away from pedestrian &amp; animal paths. |
|                                | Removal of illegal encroachments within intercity road boundaries. |
|                                | Construction of side barriers to prevent sudden crossings of pedestrians/animals. |
|                                | Construction of pedestrian bridges/tunnels to enable segregated pedestrian crossing of main roads. |
|                                | Proper road shoulders constructed/maintained &amp; used only for emergency traffic. |</p>
<table>
<thead>
<tr>
<th>Traffic-Related</th>
<th>Traffic-Related</th>
<th>Traffic-Related</th>
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</thead>
<tbody>
<tr>
<td>• Installation/improvement of road furniture (markings/channelisation/signing/lighting)</td>
<td>• Local manufacturing of traffic signals, signs, markings, guard fences to be encouraged. A road safety industry can develop that manufactures, installs and maintains these road safety features.</td>
<td>• Accident -Related</td>
</tr>
<tr>
<td>• Construction and improvement of road supporting facilities along intercity roads such as rest areas, petrol stations, vehicle repair shops, motels, etc.</td>
<td>• Traffic calming measures to be widely adopted. These measures are meant to reduce the number and the severity of pedestrian/vehicle conflicts.</td>
<td>• Establish a group of road safety engineers and technicians. These should be trained for use of microcomputers for accident data coding, storage as well as for accident data analysis, identification of black spots, countermeasures scheme design and monitoring.</td>
</tr>
<tr>
<td></td>
<td>• Warning signs &amp; speed control humps to be placed in front of schools.</td>
<td>• A reliable accident database is crucial for any safety improvement. Attention to be given to the whole process of accident data collection, storage, and analysis to systemize and ensure that it is functioning in an adequate and efficient manner.</td>
</tr>
<tr>
<td></td>
<td>• More use of intersection designs that are speed-self reducing. These include: roundabouts, curves at T-junctions.</td>
<td></td>
</tr>
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<td></td>
<td>• Provision of adequate street lighting.</td>
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<td></td>
<td>• Maintenance of traffic control devices should be well programmed.</td>
<td></td>
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<td></td>
<td>• Sidewalks to be wide enough especially in heavily pedestrianised areas to allow for a more comfortable and easy movement for pedestrians.</td>
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<td></td>
<td>• Kerbs to be dropped at pedestrians crossings to ease the crossing.</td>
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<td></td>
<td>• Crossing to be staged, on wide roads, through central refuge islands to allow pedestrians to negotiate one traffic stream at a time.</td>
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<td></td>
<td>• Roads characterised by dense pedestrian movement considered for pedestrianisation.</td>
<td></td>
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<td></td>
<td>• Hazardous locations such as open gutters, open electricity kiosks to be fenced with visual and audible warning signs.</td>
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<td></td>
<td>• Introduce, expand &amp; enhance traffic counting programs for all network.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Establish driver information system to inform &amp; warn drivers of traffic &amp; weather conditions, maintenance works, accident/incident occurrence, etc.</td>
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<thead>
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<th>Accident-Related</th>
<th>Accident-Related</th>
<th>Accident-Related</th>
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<tbody>
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<td>• Establish a group of road safety engineers and technicians. These should be trained for use of microcomputers for accident data coding, storage as well as for accident data analysis, identification of black spots, countermeasures scheme design and monitoring.</td>
<td>• Develop vehicle standards and specifications to include sufficient safety features. This is done in coordination with other concerned authorities.</td>
<td>• Develop specifications/standards for driving schools. Drivers’ instructors to be trained and tested.</td>
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<td>• A reliable accident database is crucial for any safety improvement. Attention to be given to the whole process of accident data collection, storage, and analysis to systemize and ensure that it is functioning in an adequate and efficient manner.</td>
<td>• Develop time schedules &amp; programs for mandatory vehicle inspection in accordance with type &amp; age of vehicles. This should determine road worthiness of vehicles.</td>
<td>• More tight &amp; stringent driving tests emphasizing practice &amp; knowledge.</td>
</tr>
<tr>
<td></td>
<td>• Build special stations for technical inspection of vehicles.</td>
<td>• Design a national driving handbook.</td>
</tr>
<tr>
<td></td>
<td>• Inspection procedures should be stringent so as not to allow any vehicles with serious defects to operate on the roads.</td>
<td>• Management of pick up and dropping of children in front of schools. School patrol crossings and community assistance should be encouraged.</td>
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<tr>
<th>Vehicle-Related</th>
<th>Vehicle-Related</th>
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<th>Driver-Related</th>
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<tr>
<td></td>
<td>• Develop specifications/standards for driving schools. Drivers’ instructors to be trained and tested.</td>
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</tr>
<tr>
<td></td>
<td>• School bus drivers should ensure dropping children on the road off side.</td>
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<tr>
<th>Traffic-Police Related</th>
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<th>Traffic-Police Related</th>
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<tbody>
<tr>
<td></td>
<td>• Traffic police to be well trained &amp; equipped. Special training for traffic police officers to include abilities to conduct accident investigation, deal with accident reporting, assist in victims rescue, clear accident sites, etc.</td>
<td>• Community-Related</td>
</tr>
<tr>
<td></td>
<td>• Traffic police to be well trained &amp; equipped. Special training for traffic police officers to include abilities to conduct accident investigation, deal with accident reporting, assist in victims rescue, clear accident sites, etc.</td>
<td>• Develop specialized training and educative adult programs to increase their knowledge of road safety aspects. These should be particularly targeted towards uneducated rural communities.</td>
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<tr>
<th>Community-Related</th>
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<td>• Develop specialized training and educative adult programs to increase their knowledge of road safety aspects. These should be particularly targeted towards uneducated rural communities.</td>
<td>• Quick emergency service using latest equipment for communication, well trained first aid officers, and high-speed mode for victim transportation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• More small well equipped medical centers that are specialized in dealing with accident emergency to be located in different areas so as to minimize time of transporting victims from accident sites to medical centers.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Training of traffic police officers on first aid &amp; promoting public first aid awareness.</td>
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<td></td>
<td></td>
<td>• Coordination of accident rescue operations among traffic police officers, first aid and emergency officers and hospitals.</td>
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<tr>
<th>Health-Related</th>
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<th>Health-Related</th>
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<tbody>
<tr>
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<td>• Quick emergency service using latest equipment for communication, well trained first aid officers, and high-speed mode for victim transportation.</td>
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<tr>
<th>Ministry of Interior</th>
<th>Ministry of Health</th>
<th>Ministry of Health</th>
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The above package was initially proposed by the author as a consultant to the UN and endorsed by the UNECA, 1997 report. It was further improved and translated into Arabic and proposed by the author to the Egyptian government in his contribution to the EASRT, 1999 report.

7 CONCLUSIONS

This paper started by developing a conceptualisation of components constituting road safety pyramid. In addition, a categorization of the main causes contributing to the occurrence of traffic accidents and their possible effects on road safety were presented. The paper developed a three-step procedure to assess road safety conditions in a country. First, a set of generic criteria that can be used to describe and compare the road safety culture was proposed. The second step involved a review, detailed categorisation and computation of the main road safety indicators. Finally, the third step for assessing road safety was concerned with compiling and analysing accident records and identifying accident causes.

An assessment of road safety conditions in Egypt was conducted through this three-stage procedure. In this context, Egypt served as a prototype example for developing countries. More than 40 criteria were identified and applied in an attempt to semantically assess the road safety culture in Egypt. Fatalities per million vehicle kilometers were obtained for Egypt, three other Arab countries and 6 of the G-7 countries. These were compared in an effort to determine the road safety position of Egypt. The comparison showed that Egypt stands as having a significantly very high rate of deaths per 100 million veh.km. Accident records collected in 1998 for five main rural roads in Egypt were compiled and analysed to recognise accident causes. More than 26 causes were identified. These were categorized under six main categories, namely driver related, pedestrian related, vehicle related, road related, environment-related causes and other causes.

The paper concluded with developing an integrated road safety programme composed of 16 fields of actions. Each of these contains a number of recommended policies, measures and actions targeted to improve road safety in Egypt as well as in other developing countries. These are categorized in accordance with concerned authority responsible for implementation.

REFERENCES


EFFECTIVE ROAD-SAFETY POLICY MAKING IN LOWER-INCOME COUNTRIES:
TEN PRINCIPLES FROM SOCIAL SYSTEMS THINKING

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ABSTRACT
A methodical policy intervention in road safety was designed and implemented in Chile starting in 1993, which turned out very successful. It changed dramatically a growing trend in traffic deaths and reduced deaths per 100,000 population from 13 to 10 in less than 10 years. The overall cost has been around US$ 20 million. The intervention’s methodology was the Participatory Innovation Model (PI Model), an approach to action in complex systems developed by the present author, who was the methodological consultant in this case.

This paper is intended to put forward the PI Model as a practical option for facing the road safety crisis in the lower-income world. For this purpose it presents the conceptual grounds on which it is based, it briefly describes the Model’s management principles, concepts and tools, and it shows the concrete results of the application in Chile. The paper closes by outlining a program for transferring the Model to interested countries or international agencies.

Some key aspects of the paper should be highlighted: (1) it distinguishes between two key components in any road safety policy, i.e., the technical measures and the systemic foundations, and shows that the PI Model deals with both; (2) it places road-safety policy making among “high-complexity” action problems, because of the great number and diversity of relevant issues, actors, disciplines and cultures it involves; (3) it presents the conditions for effectively facing this class of problems, which are established by an important law of systems; (4) it compares, on the basis of this law, the likely effectiveness of several approaches to road-safety policy intervention, including the PI Model; and (5) it describes the following outputs of the Chilean intervention: a critical mass of committed and mobilized road-safety actors, a powerful vision of development, the creation of a sustainable lead agency (i.e. CONASET), the effective implementation of a large number of projects, the impact on lives saved and on people saved from being injured, the low overall intervention cost, and the estimated overall economic impact of the policy, i.e., saving US$ 10 billion.

1 TWO COMPONENTS OF ANY ROAD SAFETY POLICY IN LOWER-INCOME COUNTRIES
The need to design and implement effective road-safety policies in lower-income countries is urgent and clear, and has become well-established through the important work done by WHO and the World Bank: 1.2 million fatalities and 50 million injured people per year demand urgent action. The questions to be dealt with in this paper are: (a) what kind of action is required, and (b) how could such action be effectively designed and implemented.

On Figure 1 we raise a central point to be made herewith: There are two components in any road safety policy that must be distinguished: the Technical Measures and the Systemic Foundations; typical elements of both are shown in the figure. The Technical Measures provide the specific contents of the policy, while the Systemic Foundations make the policy at
all viable in the context in which it is meant to work --namely, a political, economic, social and cultural context that is specific to some country or region. Both components need one another, since Systemic Foundations without contents would be meaningless, and Technical Measures without economical and political sustainability are bound to be short-lived.

Figure 1: The Key Components of any Road Safety Policy

Technical Measures make up the bulk of the knowledge, research, experience and expertise that is available for road safety on the global scale. A large number of such measures have been developed, tested and applied in higher-income countries, which were the first ones to become motorized and to feel the need for road safety. There is even a systematic way of identifying such measures, which is the well-known Haddon Matrix (WHO / World Bank, 2004, pp. 12-13). The existing expertise and related elements are being transferred from higher-income countries to lower-income ones.

A significant issue on Technical Measures is what mix of measures is the appropriate one for some particular country or region. The following figures show that this depends strongly on the conditions of each place: “In North America and Europe, there are between two and three people per car. In China and India, on the other hand, there are 280 and 220 people per car, respectively” (WHO / World Bank, 2004, p. 11).

The subject of Systemic Foundations of road safety policy in lower-income countries is far deeper and more difficult, because it hinges upon political, cultural and related factors. There seems to be little systematized knowledge about this subject, if any, though the importance of institutional aspects, which is one of its dimensions, has indeed been highlighted:

- The World Report on Road Traffic Injury Prevention (WHO / World Bank, 2004, p. 12) considers that “A key factor in tackling the growing road traffic injury burden is the creation of institutional capacity across a range of interlinking sectors, backed by both strong political commitment and adequate and substantial resources”.
- Giannopoulos (2008, p.8), with regard to institutional and organizational action, states: “This type of ‘action’ is a necessary prerequisite of all actions (‘soft’ or ‘hard’) mentioned in this report. There can be no hope of an effective policy making if there is
no appropriate institutional and organizational mechanism in place. Unfortunately, this aspect generally receives little attention but it is perhaps the most important.

The key practical question is how to build the Systemic Foundations under the actual conditions of lower-income countries, since they are characterized precisely by lack of political commitment to innovation in most fields and by lack of resources. Such elements cannot be regarded as pre-conditions for the design of the policy but rather as key goals to be sought by the policy. Moreover, they are highly country-specific and dependent upon culture, history and institutional setup. As a consequence, and unlike Technical Measures, the knowledge and experiences on Systemic Foundations from higher-income countries may not be applicable or even relevant to lower-income ones. But the experiences from other lower-income countries may be.

2 CHARACTERIZING ROAD-SAFETY POLICY MAKING: A “HIGH-COMPLEXITY” PROBLEM

We opened this paper by asking what kind of policy action is required for effective road safety in lower-income countries. This question led us into two more specific ones: (a) what would be the appropriate mix of technical measures in this particular country or region? and (b) how should these measures be grounded on this particular socio-political environment, in order to be viable and sustainable over the long term?

This problem belongs to the “high-complexity” class of problems, in the terminology of the PI Model. They are quite common in the real world; some examples are improving education, controlling crime and overcoming poverty. Problems of this class share six important characteristics, which will be illustrated for road safety:

- **The need for effective interaction between many types of actors**: (a) from a variety of sectors in government: health, transport, infrastructure, urban development, education, justice, police, and (b) from a variety of roles in society: state, business, universities, media, NGO, regional ones and other.

- **The need for effective interaction between several disciplines**: health sciences, transport engineering, law, police sciences, city planning, pedagogy, management sciences, economics, psychology, journalism and other.

- **The need to deal effectively with an unending list of relevant issues and themes**: advocacy, alcohol, black spots, buses, cars, drivers, drugs, education, fatalities, funding, hospital, infraction, injuries, insurance, judges, journalists, law, licensing, media, pedestrians, police, political will, regulations, research, signs, speeding, statistics, technology, ticket, traffic lights, training, trucks, and many other.

- **The need for effective communication between local, often-conflicting cultures**: political, medical, technological, judicial, police, public service, NGO, business and other.

- **The need for an active search for changes in the prevailing culture**: from cultures that attribute road crashes to fate, to cultures of safety; and

- **Other, common conditions in lower-income countries**: insufficient public awareness, low political priority, scarce political will, lack of funding relative to other societal problems, lack of reliable information, and low interest and experience in innovation.

This way of looking at the problem may fill the reader with dismay, because of our inherent tendency to simplify problems in order to make them manageable. Why bothering and looking so deep into their complexity? The reason is that this description is indeed closer to reality, and it is reality what we want to influence. It is precisely among these actors, themes, disciplines and cultures that we can find a wealth of possibilities and resources to deal effectively with the problem. In other words, we chose to deal with the whole complexity of the road safety problem because it is a unique source of wealth. The next section shows how.
3 PRODUCING RESULTS UNDER COMPLEXITY: ASHBY’S LAW

Can high-complexity problems be effectively faced? They can indeed, provided the scientific law that explains how this is possible is well understood and is properly applied. It is called the Law of Requisite Variety and was formulated by the British systems scientist W. Ross Ashby in the 1950’s (Ashby, 1956). This law is so significant for understanding how things actually work, that the main follower and expander of Ashby’s thinking, Stafford Beer, has compared it with Newton’s law of gravitation and Einstein’s law of relativity (Beer, 1979, pp. 83-84).

Ashby’s law establishes the conditions under which any particular situation in the real world can be brought under control by some appropriate control unit. For instance, how is an automobile actually controlled by its driver? or how could the violators of speed limits be effectively controlled by the police? For this purpose a measure of complexity is specified, which is called variety. The varieties of the situation and the control unit are the respective numbers of distinguishable states in which they can be. Ashby’s Law states that in order to have the situation under control, the variety of the control unit must be at least as large as the variety of the situation.

Let us examine Figure 2: a traffic light is performing as the control unit for an intersection of two streets. The situation in the picture is clearly out of control, but it could have been placed under control by means of a traffic light and the rules that come with it. The variety of the situation is 3, because we can distinguish three states of the traffic flow: (1) vehicles in street A are moving, (2) vehicles in street B is moving and (3) moving vehicles in any street are reducing speed to zero to leave the intersection free for those of the other street. Since the variety of the traffic light is also 3, it could provide the required control.

Let us move now one step further into complexity and consider a high-flow situation, in which turns are made by vehicles from both streets. The simple traffic light is no longer sufficient because variety is now much larger and traffic flow becomes often obstructed by the turning vehicles. What can be done? Ashby’s law shows two clear options: (a) reduce the
variety of the situation (e.g., one-way streets, no left turns) or (b) increase the variety of the control unit (e.g., four-way traffic lights, left-turn light, computerized traffic lights). Notice that the law is always in operation; it is a logical law and cannot be violated.

The general applicability of Ashby’s Law may become clearer through Figure 3. Each football player tries to beat his opponent by matching his moves with his own moves, and if possible by taking the ball from him. The variety of each player is, precisely, his available repertoire of moves. Varieties are balanced if they are players of the same level and are out-of-balance if their levels are different. Notice from this example that we do not need to count varieties in order to see the law working.

![A Situation of Mutual Control](image)

We complete this section by drawing two practical consequences from Ashby’s Law, which are key to the discussion that follows in the rest of the paper: (1) the entire practice of management in any field is contained in Ashby’s Law, since we are permanently curtailing situational varieties and expanding control varieties in order to make things work; whenever things fail to work, there is some unbalance of varieties to explain why; (2) a high-complexity situation, which has exceedingly high variety, can in principle be also brought under control if an adequate, high-variety control unit is designed and implemented for managing it.

4 COMPARING APPROACHES TO ROAD-SAFETY POLICY MAKING IN LOWER-INCOME COUNTRIES

We are now prepared to review some of the approaches that are practiced or advocated for road-safety policy making in lower-income countries. By following Ashby’s law, we will compare the actual, high-complexity variety of the road safety situation, with the variety-handling power of the proposed methods. The approaches to be reviewed are four: (a) the Motivated Minister approach, a conceptual description by the author of the common-sense approach followed typically in lower-income countries, (b) the proposals included in the World Report on Road Traffic Injury Prevention of 2004, (c) the proposal put forward by Giannopoulos (2007) and (d) the Guidelines issued in 2009 by the World Bank Global Road Safety Facility (Bliss and Breen, 2009). The author’s Participatory Innovation Model, to be presented in the rest of the paper, is also included in the comparison on Table 1. The ratings are grounded on the discussion that follows.

In the Motivated Minister approach, a minister of health or transport is interested in setting up a process of road safety improvement in her country, in which there is limited experience in this field and no agency in charge. How would she start working? According to common sense, she would: (a) use experts, consultants, surveys and analyses of varied sorts as her sources of knowledge, and (b) take one or two highly-visible measures like seat-belt or speeding enforcement, with the support of a strong media campaign. Notice that this approach
deals with the complexity of the situation by simplifying it, in order to make it manageable. She does not cover the whole situation, but just what she believes she can handle. Will this work for the long run? Unfortunately not, since the next minister, who needs to differentiate to survive politically, may not support the same measures and launch his own ones, but only if he feels that road safety is still attractive at all. The experience may leave a strong frustration among those involved, and may postpone any attention to road safety for another decade. And it will certainly leave little or no sustainable Foundations in place.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Motivated Minister</th>
<th>WHO/WB W Report</th>
<th>Giannopoulos</th>
<th>W Bank GRSF</th>
<th>PI Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy Inputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Including all relevant actors</td>
<td>Low</td>
<td>Nil</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Including all relevant disciplines</td>
<td>Nil</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Handling large number of issues</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Communicating local cultures</td>
<td>Low</td>
<td>Nil</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Active search for changes in culture</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Facing lower-income facts (*)</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td><strong>Policy Outputs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applying wide scope of Techniques</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Building Sustainable Foundations</td>
<td>Nil</td>
<td>Nil</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

(*) Common conditions in lower-income countries: insufficient public awareness, low political priority, scarce political will, lack of funding relative to other societal problems, lack of reliable information and low experience with innovation.

Table 1: Variety-handling power of approaches to road-safety policy making

The main focus of the World Report (2004) is placed on the technical measures: “In high-income settings, new strategies and programmes for traffic injury prevention generally require considerable analysis and planning before implementation. In developing countries, though, because of the scarcity of resources, the priority should be the import and adaptation of proven and promising methods from developed nations, and a pooling of information as to their effectiveness in the imported settings among other low-income countries” (Ibid., p. 12). It does include recommendations about institutional development (Ibid., p. 159), such as making road safety a political priority, appointing a lead agency and giving it adequate resources. The key difficulty with these recommendations is that they are fully dependent on the pre-existence of interest in road safety and of political will to provide it with support and resources; but this is precisely what lower-income countries lack, and what they need most urgently. The report takes this matter for granted and includes no discussion about it.

Giannopoulos (2007) focuses on “non-infrastructure” or “softer” road safety measures, which “can be developed and implemented with relatively less investment and in shorter times” than measures related to infrastructure or ITS. He proposes seven specific measures: (a) road safety education and awareness raising campaigns, (b) driver education, training and licensing, (c) rehabilitation and re-licensing of existing drivers, (d) better maintained vehicles, (e) enforcement and monitoring actions, (f) institutional and organizational strengthening and (g) post accident care. The institutional aspects in measure (f) call for active planning work by a multi-disciplinary body, and for the creation of “centers of excellence” in various parts of the country for local adaptation of solutions. He calls for active involvement of national actors in developing and implementing the policy.

The 2009 Country Guidelines from the World Bank (Bliss and Breen, 2009) do make a significant contribution to establishing a workable approach in developing countries. A conceptual model of the required road-safety management system is specified in detail on the basis of the experiences of the leading developed countries, and is applied with practical
guidelines to (a) conducting capacity reviews at the country level, (b) specifying an investment strategy and identifying projects, and (c) preparing and implementing projects. The document includes a wealth of practical checklists, conceptual details about lead-agency functions, country case studies and much more.

5 TEN WORKING PRINCIPLES FROM SOCIAL-SYSTEMS THINKING

We move now to our specific proposal, called the Participatory Innovation Model (PIM). For this Model the challenge is not just to implement a few Technical Measures but a large number of them, and to do this synergically. Our central question may be restated as follows: How to build up an effective and sustainable road-safety system, which may design and implement a permanent stream of diversified Technical Measures? The need for appropriate Systemic Foundations for road safety (see Section 1) is of course implicit in this question.

Following Ashby’s Law, the key to an effective approach is to match the high complexity of the road safety situation –rather than ignoring, missing or simplifying it– by building up an action capability that has the requisite variety. We have developed and applied with success a set of ten managerial principles that make that possible. They are presented on Table 2.

<table>
<thead>
<tr>
<th>Ten Working Principles for Managing High-Complexity Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Understand road safety as a social system – not a physical or technical one: The physical effects of road safety actions, in any particular situation, take place in the context of broader interactions in the political, social, economic and cultural spheres of society. The action capability to be built should be able to impact upon such broader spheres and should be understood as a system of social actors rather than a physical or technical system.</td>
</tr>
<tr>
<td>2. Declare the political intention to build a wide action system: This is a key act of leadership. It was accomplished in the Chilean case by coining the name National Road Safety System and by stating that the central objective was to build such a wide-ranging system. This idea proved motivating and provided a concrete and practical focus for generating political will and for mobilizing action capabilities from many areas of Chilean society.</td>
</tr>
<tr>
<td>3. Aim at knowing and actualizing the whole potential involved: There is always a huge development potential behind any complex social system, which is latent and in principle can be materialized. In road safety it is often visualized via idealized goal-setting (such as Vision Zero), benchmarking studies or other procedures. Visualizing the whole system potential provides strong motivation for the actors to participate.</td>
</tr>
<tr>
<td>4. Mobilize a large and diverse number of people around this future-building task: This is the most effective way to make sure that the whole complexity of road safety will be considered and no aspect of it will be missed. The people’s stock of knowledge, experience and valuable insights is huge. Moreover, people are normally willing to contribute, provided they will be respected and acknowledged, and not exploited.</td>
</tr>
<tr>
<td>5. Apply an enabling leadership style – not a domineering one: A truly effective leader in the complex world is the enabler of people to contribute proposals and actions, not the controller of people. By facilitating the rise of new actors, such a leader will have wide coverage of the field and faithful allies. A usual excuse for the domineering style, i.e., the supposed ineffectiveness of participation, is based on a confusion of participation with assembly-like activities.</td>
</tr>
<tr>
<td>6. Let the real-world actors create – not just the technicians: All interested ones should be allowed to make proposals and contribute to implementation. Experts usually know more about means, but real-world actors –managers, operations engineers, architects, teachers, road designers, health officers– know better the ends to be pursued and know the practical details.</td>
</tr>
<tr>
<td>7. Use specialized tools to externalize people’s knowledge: Non-expert knowledge, though huge, is rarely tapped because it is not formalized and readily-available, or explicit. In knowledge-management terms it is tacit, and needs to be externalized. This difficulty is solved through the special methods and tools of the Participatory Innovation Model, the outputs of which will be presented further on. In terms of Ashby’s Law, they are high-variety methods and tools.</td>
</tr>
</tbody>
</table>

Table 2: Ten working principles for managing high-complexity systems
### Ten Working Principles for Managing High-Complexity Systems (continued)

8. **Generate via participation a clear blueprint for the system to be built:** The blueprint is prepared through the *action map* tool (see section 7). It facilitates the leadership and coherence of the process by providing a clear vision of development of the system to be built. This map provides a content-rich structure for achieving a common understanding of the system and for managing in practice the process of building it up, i.e., the design and implementation of the policy and its specific projects.

9. **Implement a large number of inter-related and realistic projects:** The high complexity of road safety, which is a multi-dimensional challenge, is matched with a large number of projects that cover all dimensions. No “star” project can match such complexity by itself. Projects are identified via participation to secure their realism, are designed in mutual interaction to secure their overall impact, and are normally implemented as joint-ventures with participating actors.

10. **Set up a multi-actor management system:** An integrated management system for the whole process is essential, but should not be built until the blueprint of the system and the first significant group of projects are well defined. Otherwise it may become just another instance of power struggles. It should have a management team with systemic vision and social and technical strengths, deal with both strategy and operations, and evaluate and re-design periodically the system through participation.

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**Table 2 (continued): Ten working principles for managing high-complexity systems**

#### 6 THE PARTICIPATORY INNOVATION MODEL (PIM) IN PRACTICE

In a previous paper (Del Valle, 2007) we have presented details and references about the PI Model along with details of its application to Chile’s road safety policy. This Model involves concepts, methods, techniques and tools, on which the author has worked over 30 years. Applications have been made in many fields beyond road safety, such as energy, the environment, technology, education, innovation policy and urban development. Following is a short synthesis about its methods and tools.

**6.1 The high-variety tools**

The PI Model includes three tools for dealing with complex situations by handling high levels of variety, which are language-based tools rather than mathematical tools and are always used through participation. They are: (a) the *Action Map*, for making high-complexity problems understandable and manageable, and for generating strategic agendas and visions of development; (b) the *Potentiality Profile*, for designing conceptually complex projects and for systematizing successful experiences; and (c) the Internet-based *Participatory Workspace*, for designing inter-personal networks and knowledge management systems. They are applied through techniques that unleash intuitions methodically and systematize them interactively.

**6.2 The methodological steps**

The PI Model mobilizes actors for co-creating development in a particular field, by means of the following methodological steps: (a) constitution of a *Group of Conveners* to provide overall guidance; in Chile’s policy its members were eight Ministries and the National Police (Carabineros); (b) creation and validation of a *Vision of Development* through an *Action Map*; in Chile’s policy it involves nine lines of action and was validated by 120 actors; it is presented on Table 2; (c) definition of a *Project Portfolio*; it involves 130 project profiles and was prepared through a series of workshops with more than 200 actors; and (d) design of the *Management System*, to conduct the technical design and implementation of the projects; it led to the creation of Chile’s national road safety agency, CONASET.
6.3 The intangible outputs and cultural change
The above steps yield not only the tangible outputs that were just described. Because of the participatory approach they also produce a key set of intangible outputs that belong to the cultural sphere and are essential for the success and sustainability of any high-complexity process. Such outputs are: an integrating language, awareness of the potential, motivation, consensus, trust, leaderships, alliances, networks and permanent innovation capacities.

7 OUTPUTS AND IMPACTS OF THE PI MODEL: CHILE’S NATIONAL ROAD SAFETY POLICY

We shall now review briefly the outputs and impacts of Chile’s National Road Safety Policy. Further details are available in our previous paper to RS4C (Del Valle, 2007).

7.1 A critical mass of committed and mobilized road-safety actors
There is little doubt that a key enabler of Chile’s road safety policy was the constitution of a critical mass of people committed to road safety, who were actively involved as co-creators of the policy. All actors, disciplines and cultures considered in our characterization of road safety (Section 2) were represented. The policy was developed by them, not just for them, and they felt a clear sense of ownership all along the process. This extensive group, which initially involved some 200 people and kept growing, remained motivated and loyal to CONASET. There is little doubt that this large followership and contact network was crucial for saving CONASET from the typical process of disappearance once political support is reduced, as discussed above in the presentation of the Motivated Minister approach (see Section 4).

7.2 Vision of development: The Action Map of the system
The Vision of Development of the National Road Safety System, that reflects a consensus of the road safety actors and provided a common language to them, is presented on Table 3.

<table>
<thead>
<tr>
<th>Action Map (1993): THE NATIONAL ROAD SAFETY SYSTEM OF CHILE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong> Training and certification of drivers</td>
</tr>
<tr>
<td>A-1 Training professional drivers</td>
</tr>
<tr>
<td>A-2 Training particular drivers</td>
</tr>
<tr>
<td>A-3 CERTIFICATION OF DRIVERS</td>
</tr>
<tr>
<td>A-4 Training driving instructors</td>
</tr>
<tr>
<td>A-5 CERTIFICATION OF INSTRUCTORS</td>
</tr>
<tr>
<td>A-6 Certification of examiners</td>
</tr>
<tr>
<td>A-7 CONTROL OF DRIVING SCHOOLS</td>
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<td>A-8 Permanent qualification of drivers</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td><strong>B</strong> Management of vehicle quality</td>
</tr>
<tr>
<td>B-1 Technical specifications</td>
</tr>
<tr>
<td>B-2 Safety equipment</td>
</tr>
<tr>
<td>B-3 Certification of new vehicles</td>
</tr>
<tr>
<td>B-4 Effective technical inspection</td>
</tr>
<tr>
<td>B-5 Control of inspection plants</td>
</tr>
<tr>
<td>B-6 Control de maintenance workshops</td>
</tr>
<tr>
<td>B-7 Training of mechanics</td>
</tr>
<tr>
<td><strong>C</strong> Management of roads and public spaces</td>
</tr>
<tr>
<td>C-1 Traffic management</td>
</tr>
<tr>
<td>C-2 Management of traffic signals</td>
</tr>
<tr>
<td>C-3 Updating of designs</td>
</tr>
<tr>
<td>C-4 Maintenance</td>
</tr>
<tr>
<td>C-5 Road safety implements</td>
</tr>
<tr>
<td>C-6 Stops and rest areas</td>
</tr>
<tr>
<td>C-7 Facilities for pedestrians</td>
</tr>
<tr>
<td>C-8 Facilities for cyclists</td>
</tr>
<tr>
<td>C-9 Location of activities</td>
</tr>
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<td></td>
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<tr>
<td></td>
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</tbody>
</table>

Table 3: The Action Map of Chile’s National Road Safety System (1993)
The components of the Action Map are called lines of action and should be understood as inter-dependent actions. There are 9 basic lines (A to I), which are on boldface and correspond to the dimensions of road safety, and 57 specific lines (A-1 to I-5) that provide contents and precision to the basic ones. Only 9 specific lines of action (and no basic one) were considered established at the time, i.e., having actors in charge and being able to make impact; they are presented in upper case letters. This map provided the actors with (a) a diagnostic review of the degree of development of the road safety system in Chile at the time, and (b) a clear and motivating blueprint for the system to be developed.

7.3 Management system: The creation of CONASET
The National Road Safety Commission, CONASET, was formally created at the end of 1993, as an inter-ministerial entity to advise the President of the Republic, and started operations in March 1994. It consists of a Committee of Ministers chaired by Transport (whose members are the same as the original Group of Conveners) and an Executive Secretariat. The internal organization of the Secretariat reflected from the beginning the structure of the Action Map.

7.4 Project identification, design and implementation
One of the first tasks of CONASET was to organize the participatory process through which 130 projects were identified and conceptualized by the road-safety actors. It involved more that 200 participants, in 30 workshops that applied the Model’s tools and techniques, and followed the structure of the Action Map. The report of this process (CONASET, 1995), including conceptual designs for all projects, has become a consultation source that carries the legitimacy of belonging to 200 authors, and that 15 years later keeps its full validity.

Project implementation started at once and over the years led to executing most of the initiatives proposed by the participants. A ten-year evaluation report prepared by CONASET (2004) showed that 76 projects had been implemented. This large number corresponds to one of the working principles of the PI Model and contributes to explain the success of the policy.

Tables 4, 5 and 6 show, for each basic line of action, the projects that had been implemented by the end of 2004, including those carried out in a different way than envisaged at the beginning. The tables also compare the number of projects actually implemented with the total number identified at the initial exercise en 1994-95.

<table>
<thead>
<tr>
<th>A. Training and certification of drivers</th>
<th>Identified: 9</th>
<th>Implemented: 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation of principles for responsible behavior in road traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of a manual for the competent driver</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B. Management of vehicle quality</th>
<th>Identified: 17</th>
<th>Implemented: 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation and application of an official norm for light vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulation and application of an official norm for heavy vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulation and application of an official norm for two- and three-wheel vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ban on the circulation of hand-made, non-certified vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norm on day-time running lights</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulation of the circulation of special vehicles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norm on information plate in passenger transport to facilitate user complaints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correction of tax distortions against vehicle safety equipment (“tax on luxury”)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correction of tax distortions favoring inadequate vehicles for urban traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National certification of technical inspection mechanics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legal specification of fraud situations in technical inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High penalties for circulation without approved technical inspection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use and extension of tax incentives for training transport companies and fleets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norm on safety equipment for children in light vehicles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Table 4: Projects with full, high or medium degree of implementation: Lines A and B.
### C. Management of roads and public spaces

<table>
<thead>
<tr>
<th>Identified</th>
<th>Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>17</td>
</tr>
</tbody>
</table>

- Formulation of safety criteria for design and operation of roads and public spaces
- Homogenization of terminology among ministries, municipalities and other
- Development of the responsibility for safety management in primary and secondary road networks
- Traffic management training programs
- Treatment of black spots with low-cost measures
- Methodology for incorporating road safety components into road-impact and urban-impact studies
- Improving and enforcing norms for protection of inter-urban corridors
- Recovery of role and safety conditions in high-risk sections of inter-urban roads
- Treatment of settlements or urban areas that became degraded because of vehicle-flow pressure
- Gradual decentralization to municipalities of urban road repair works
- Improvement of safety norms for repair work in roads and public spaces
- Improvement and application of norm on criteria for signaling
- Development of norm on facilities for handicapped persons
- Development of norm on urban publicity to avoid visual and circulation interferences
- Development of norm and creation of awareness about visual obstacles
- Authorization to municipalities to confiscate and auction off unattended animals on public roads
- Development of norm on design and installation of street humps

### D. Management of transport services

<table>
<thead>
<tr>
<th>Identified</th>
<th>Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>10</td>
</tr>
</tbody>
</table>

- Control of driving hours
- Network of rest, service and security areas for trucks in highways
- Regulation of circulation, loading and unloading of trucks in urban areas
- Design of expeditious system for passenger information and complaints
- Mandatory safety belt and anchored seats for inter-urban buses
- Separation of driving and collecting in urban buses
- Design of a new compensation system for urban bus drivers to avoid street races and promote quality
- Habilitation of bus terminals for urban passenger services
- Taking and leaving school children inside schools
- Mandatory safety belt for children in school transport

### E. Enforcement

<table>
<thead>
<tr>
<th>Identified</th>
<th>Implemented</th>
</tr>
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<tbody>
<tr>
<td>9</td>
<td>2</td>
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</table>

- Identification of up-to-date enforcement techniques
- Implementation of breath alcohol testing

### F. Judicial action

<table>
<thead>
<tr>
<th>Identified</th>
<th>Implemented</th>
</tr>
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<tbody>
<tr>
<td>9</td>
<td>7</td>
</tr>
</tbody>
</table>

- Revision of the penalties system to induce safety behavior through its intimidatory capacity
- Development of re-education programs as sanctions
- Effective procedure for sanctioning driving without license or with suspended or cancelled license
- Revision and updating of the procedure for accumulation of infractions
- Mechanism for expeditious consultation and updating of the registries of drivers and vehicles
- Simplification of procedure in accusation for simple infraction
- Mandatory alcohol test for drivers involved in traffic accidents

### G. Accident care and insurance

<table>
<thead>
<tr>
<th>Identified</th>
<th>Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>8</td>
</tr>
</tbody>
</table>

- Manual for coordinating procedures in integrated rescue operations
- Integrated rescue training program
- Updating and dissemination of maps of emergency medical care units
- Development of medical regulation of rescue and transfer
- Public dissemination program about behavior at accidents
- Assessment of effectiveness and procedures of the existing mandatory insurance
- Expansion of coverage of the mandatory insurance to total costs of rescue and rehabilitation
- Disconnection of indemnity for death and medical expenses in mandatory insurance


Table 5: Projects with full, high or medium degree of implementation: Lines C to G
### Table 6: Projects with full, high or medium degree of implementation: Lines H and I

<table>
<thead>
<tr>
<th>H. Research and information</th>
<th>Identified: 14</th>
<th>Implemented: 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularization of vehicle ownership records and permanent updating of home addresses</td>
<td></td>
<td></td>
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<tr>
<td>Geographical focusing of traffic accident statistics</td>
<td></td>
<td></td>
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<tr>
<td>Information to facilitate collection of mandatory insurance for care in health institutions</td>
<td></td>
<td></td>
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<tr>
<td>Incorporation of road safety contents in professional curricula</td>
<td></td>
<td></td>
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<tr>
<td>Computerized documentation centre on road safety</td>
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<tr>
<td>Development of graduate studies on road safety</td>
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<tr>
<td>Periodical seminars and conferences on road safety research</td>
<td></td>
<td></td>
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<tr>
<td>System for follow-up of measures and evaluation of impacts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assessment of accident-related factors of origin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Education and communications</td>
<td>Identified: 14</td>
<td>Implemented: 7</td>
</tr>
<tr>
<td>Incorporation of the principles for responsible behavior in road traffic into school curricula</td>
<td></td>
<td></td>
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<tr>
<td>Training of teachers in road safety</td>
<td></td>
<td></td>
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<tr>
<td>Development of teaching material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promotion of use of tax incentives for training in road safety</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources network for motivation in formal and non-formal education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training journalists to educate while informing about accidents</td>
<td></td>
<td></td>
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<tr>
<td>Permanent and focalized dissemination campaigns</td>
<td></td>
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</tbody>
</table>

#### 7.5 The impacts of Chile’s Road Safety Policy: A dramatic trend change

The impact of Chile’s Road Safety Policy is very significant and is presented on Figure 4. A long-standing growth trend in road deaths was broken as a consequence of this process, and was replaced by a plateau trend, just a few years after the Policy was formulated and its implementation began. The fact that this change in trend did come from the road safety policy may be ascertained from two elements: (a) no economic change can explain it, since Chile’s GDP and transport system kept growing steadily throughout the years under consideration, as seen on Figure 5; and (b) the situations in neighboring Argentina and Peru, for approximately the same period and with no equivalent policy, show no equivalent behavior on Figure 6.

An illustrative estimate of the number of lives saved can be made by comparing the actual number of deaths with a linear projection of the previous trend, taken as a proxy of the situation without a road safety policy. This includes, of course, the strong assumption that no road safety measure was taken. By doing so it is estimated that 7,000 to 8,000 lives were saved, in this country of 16 million since, and that 70,000 to 80,000 people were saved from injuries in ten years since the death/injury rate in Chile is around 10. On the world scale, this impact amounts to saving 3 million lives and saving 30 million or more people from injuries in ten years. It should be added that for Chile the standard indicator for international comparisons, i.e. traffic deaths per 100,000 inhabitants, went down from around 13 in 1985 to around 10 in 1999 and has remained at this level over the last decade (www.conaset.cl). This is the average level of the indicator for high-income countries (WHO, 2009, p. ix).

#### 7.6 The cost-effectiveness of Chile’s Road Safety Policy

The cost of Chile’s Road Safety Policy is also relevant to this discussion. The key fact is that such cost has consisted almost exclusively in covering CONASET’s budget in the Ministry of Transport and Telecommunications: around US$ 1.5 million per year (source: CONASET). Thus, total cost for the whole 1994-2009 period amounts only to some US$ 20 or 21 million.

The cost-effectiveness of this policy was very high. The annual cost of road crash injuries is estimated at 1.5 % of GDP for middle-income countries (WHO / World Bank., 2004, p. 5). Since 7,500 lives is equivalent to the current death toll from road crashes of four years in Chile and since Chile’s GDP in 2008 was US$ 169.5 billion (World Bank, 2009), *this policy is estimated to have saved costs equivalent to 6% of Chilean GDP, or US$ 10 billion.*
Figure 4: Chile’s National Road Safety Policy and its impacts, 1985-2008

Figure 5: Chile’s GDP growth in the 1985-2008 period

Figure 6: Equivalent time series for two neighboring countries
7.7 Some influences of the experience beyond Chile

The experience in Chile has had some influence in other countries, in spite of the fact that its methodological model has not yet been formally transferred. The following experiences can be mentioned: (a) the first Executive Secretary of CONASET has been a consultant to the governments of Poland, Nicaragua and Iran, and has disseminated the approach applied in Chile (Bertin-Jones, 2009); (b) an active participant in the process from Chile’s National Police was in charge of a training program in road safety for Bogota’s Metropolitan Police; the Bogota experience, including the role of the police, was subsequently highlighted by the World Report (WHO/World Bank, 2004, p. 15); (c) training and consulting activities have been carried out in Ecuador by another Chilean expert with very active participation in the process.

7.8 Why did mortality not keep falling? Political difficulties in the 2000s

The PI Model is certainly no panacea, and the experience in Chile did face strong difficulties as any action process in the real world. In our view, such difficulties may explain why the mortality rates did not fall beyond 2002. The key difficulties were related to political will and political priorities. Two significant situations will be mentioned.

The first one took place in the government of President Lagos (2000-2005), in which the Ministry of Transport and Telecommunications lost political weight by becoming a part of the Ministry of Public Works, and CONASET also lost weight and was given tasks unrelated to its mission, such as the design of a bicycle promotion program. But it survived, because of its stable budget in the Transport Under-secretariat and of the strong network of allies that had been established in the original participatory process. However, its weakness left it with no access to the Minister and no chance of pushing any new initiatives. As a lesson learned, subsequent PI Model applications in public policies have always involved representatives from the private sector, academia and in civil society in their Groups of Conveners, in order to have a greater chance of continuity when governments change.

The second difficult situation took place at the beginning of President Bachelet’s government (2006-2009). The Ministry was again autonomous and CONASET was again able to take initiatives. In mid-2006 the present author was asked by CONASET to provide methodological support to a new participatory process, in order to update the Road Safety Policy, since the first one had clearly completed its cycle. The process took place in the second half of 2006, involved more than 100 participants, generated a new Action Map and a new Project Portfolio, and even left the conceptual profiles of 18 priority projects ready for implementation. Unfortunately, the whole process had to be stopped and discontinued because of an emergency in the Ministry at the beginning of 2007: a comprehensive redesign of the public transport network of Santiago, called Transantiago, had collapsed because of severe deficiencies in design and implementation, and had become the government’s number one political problem. The Minister fell and the new one had to devote all his energies to solving Transantiago. Not a single strategic road-safety initiative could again be taken.

8 TRANSFERING THE PARTICIPATORY INNOVATION MODEL TO LOWER-INCOME COUNTRIES: OUTLINE FOR A PROPOSAL

Following are the basic ideas for an “International Program for Capacity Building in Road Safety through Participatory Innovation Methods” that could be established at Universidad Alberto Hurtado, Chile. This university has become the home of the PI Model since 2005 and is a part of the Network of Jesuit Universities, with 202 universities in all continents. The Program would contribute to facing the road-safety crisis of the lower-income world by
making available the Model to multi-organization teams from the interested countries, through integrated training-and-consulting projects.

The Program’s focus will be placed on the overall policy making process and the Systemic Foundations for road safety. It will thus be a complement to other efforts focused on Technical Measures. The initiative has the support of CONASET in Chile and is available to cooperate with governments and international agencies in the design, implementation, follow-up and networking of projects which apply its methods and tools. The basic design of its project cycle involves seven phases, which are outlined on Table 7.

<table>
<thead>
<tr>
<th>Basic design of the Program for Capacity Building in Road Safety through PI Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>The training-and-consulting process will have the following phases:</td>
</tr>
<tr>
<td>1. <strong>Framework agreement with interested government and/or agency</strong>: Definition of commitments for project execution, including evaluation of results and impacts.</td>
</tr>
<tr>
<td>2. <strong>Initial steps of the PI process</strong>: Setting up a Group of Conveners, formulating the Action Map, building up an initial Strategic Project Portfolio and defining implementation priorities through methodical activities.</td>
</tr>
<tr>
<td>3. <strong>Selection of participating organizations and individuals</strong>: Identifying candidates and selecting a Technical Team of 15 -20 participants from the relevant sectors (transport, health, education, urban planning, justice, etc.), relevant actors (government, business, civil society, university) and relevant disciplines (engineering, medicine, psychology, law, pedagogy, etc.).</td>
</tr>
<tr>
<td>4. <strong>Special course on participatory development of public policies for road safety</strong>: An intensive, one-month course at Universidad Alberto Hurtado for training the whole Technical Team in systemic foundations for road safety and participatory design and implementation of road safety projects. It concludes with fully-developed grounds for a national policy, which involve: (a) detailed designs of strategic projects prepared interactively by the participants, with the support of specialists, and (b) the proposal for an implementation strategy.</td>
</tr>
<tr>
<td>5. <strong>Support for the design (or redesign) of the Lead Agency for road-safety</strong>: Consulting work, done in interaction with the Group of Conveners and the Technical Team, for the institutional and managerial design (or redesign) of the Lead Agency for road safety. It ought to be capable of providing political leadership and effective supervision to the whole set of strategic projects.</td>
</tr>
<tr>
<td>6. <strong>Consulting work for implementation and methodical follow-up</strong>: Provision of continued methodological support to the Lead Agency and the Technical Team to make sure that both tangible outputs and intangible or cultural outputs from the program are actually achieved.</td>
</tr>
<tr>
<td>7. <strong>On-line interaction through a Participatory Workspace (PWS)</strong>: A permanent connection of all national projects and their members through this inter-personal network, which will perform as a knowledge, learning and communications facility on Road Safety for all participating countries.</td>
</tr>
</tbody>
</table>

Table 7: Basic design of the Program for Capacity Building in Road Safety through PI Model

9 **CONCLUSIONS**

This paper has presented the experience of Chile’s National Road Safety Policy, which was formulated and implemented between 1993 and 1999 through the Participatory Innovation (PI) Model, and has proposed that this Model be considered as a proven and practical option for facing the road-safety crisis of the lower-income world. The following elements show this proposition to be supported on strong grounds:

- **Solid theoretical bases**: The PI Model is theory-based, having its grounds on Social Systems Thinking (Ackoff, 1981) and Complex Thinking (Morin, 1990).
• Focus on the conditions of lower-income countries: The PI Model was developed in the lower-income world, and for the specific needs and cultural characteristics of this world, which are deeply different from those of the higher-income world. For practical purposes the most significant differences lie in their relative capabilities of innovation.

• Realism vis-à-vis road-safety complexity: The PI Model is able to deal with the whole complexity of road safety, which involves large numbers of actors, issues, disciplines and cultures. Running against common sense it does not simplify, but makes use of this complexity and turns it into a wealth of insights and initiatives.

• Practical steps and powerful tools: The PI Model involves a well-specified set of methodological steps to be followed, and applies its own (high-variety) tools, thus providing a clear guidance to the policy intervention process.

• Successful experiences: The Chilean Road Safety Policy, designed and implemented through the PI Model, was indeed successful, as described presently.

• Learning from failures: This Policy did face severe difficulties from the political side, which led to learning about key methodological steps. Other PI Model experiences (some 70 as a whole, both successful and failed) have also provided valuable lessons.

• Possibility of transfer and dissemination: Conditions are prepared for the transfer and dissemination of the PI Model through Alberto Hurtado University in Santiago, Chile.

REFERENCES
Bertin-Jones, Milton (2009), The design of a management structure for road safety based in systems methodology. Accepted for publication in Traffic Engineering and Control.
Bliss, Tony and Jeanne Breen (2009), Country guidelines for the conduct of road safety management capacity reviews and the specification of lead agency reforms, investment strategies and safe system projects. World Bank Global Road Safety Facility, 307 p.
CONASET (1995), Potentialities for the improvement of road safety in Chile. Executive Secretariat, National Road Safety Commission, Santiago, May, 88 p. [In Spanish.]
CONASET (2004), Potentialities for the improvement of road safety: An evaluation 10 years after their formulation. Executive Secretariat, National Road Safety Commission, 44 p. [In Spanish.]
Del Valle, Alfredo (2007), Initiating road safety policy through participation: A successful experience with a Chilean methodology. Proceedings, 14th International Conference Road Safety in Four Continents, Bangkok, 14-16 November.
Giannopoulos, G.A. (2007), Road safety in countries with less-developed infrastructures. Issues and actions to maximize effect with minimum resources. Proceedings, 14th International Conference Road Safety in Four Continents, Bangkok, 14-16 November.
Urzúa, Julio (2006), National Road Safety Commission: Achievements and challenges. Presentation by CONASET’s Executive Secretary at the Latin American and Caribbean Planning Meeting on Road Safety, 16 slides, Santiago, 18-19 January. [In Spanish.]
World Bank (2009), World Development Indicators database, consulted on 1 July 2009.
Contents session 4  Highlights of road safety in Europe – FERSI endorsed research

Driving Under the Influence of Drugs, Alcohol and Medicines: DRUID Project
Horst Schulze, Bundesanstalt für Straßenwesen (BASt), Germany

Integrated System for Safe Transportation of Children to School, “SAFEWAY2SCHOOL“
Anna Anund, VTI, Sweden

Naturalistic Rider Studies for the Analysis of Riders’ Behaviour and Safety “2BESAFE”
Stéphane Espié, INRETS, France

PROmoting real Life Observations for Gaining Understanding of road user behaviour
In Europe (PROLOGUE)
Ingrid van Schagen, SWOV Institute for Road Safety Research, The Netherlands

SAFERIDER: Can Based Architecture on 2-wheelers Domain
Roberto Montanari, University of Modena & Reggio Emilia, Italy

Integrated Safety & Security for Transportation Hubs – SAVE ME
Maria Panou, Hellenic Institute of Transport. Greece
DRIVING UNDER THE INFLUENCE OF DRUGS, ALCOHOL AND MEDICINES: THE “DRUID” PROJECT

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ABSTRACT
The number of accidents that can be attributed to driving under the influence of psychoactive substances (alcohol, drugs, and certain medicines) is constantly on a high level with drugs and medicines proportionally increasing over the years.

The overall objective of the EU 6th Framework Programme project DRUID is to gain better knowledge of the various aspects of driving under the influence of drugs, alcohol and medicines. DRUID wants to offer scientific support to EU transport policy makers by suggesting guidelines and measures to combat impaired driving.

To reach this ambitious aim a wide range of studies is conducted. The various studies are divided into seven work packages with complex interdependencies. There are experimental studies assessing the effects of single and combined psychoactive substances on driving performance (WP1) as well as epidemiological studies aiming to assess the situation in Europe regarding prevalence of alcohol and other psychoactive substances in drivers (WP2). The principal objective of these studies is to gain relative risk estimates for traffic accident involvement of drivers impaired by psychoactive substances and to recommend substance concentration thresholds. A theoretical framework which allows the integration of the experimental and epidemiological findings serves as a fundament for developing these recommendations.

WP3 aims at improving the possibilities of detecting drug driving in Europe. Police forces evaluate practically (under realistic enforcement conditions) oral fluid screening devices. A scientific evaluation of oral fluid screening devices and other methods (i.e. roadside checklists of signs of impairment) is done as well. The outcome of the practical and scientific evaluations serves as input to cost-benefit analyses of enforcement.

DRUID partners in WP4 develop an empirically based classification and categorisation system which allows a consistent labelling of medicines with respect to their impact on driving. A ‘generic’ manual for training health care professionals is developed, based on experiences in Belgium, Spain and the Netherlands. Partners discuss the applicability of the protocols and guidelines in EU countries and some countries outside the EU and present proposals for developing state-of-the-art educational training programmes.

Another focus within DRUID is to find (propose, establish) rehabilitation systems for drivers who used to drive under the influence of the psychoactive substances (WP5). Rehabilitation measures and assessment procedures are reviewed in the member states. Existing quality management systems are analysed and an evaluation instrument for best practice is developed. These activities have already completed successfully. The following results can be presented:
• Most comprehensive literature analysis.
• Most substantial provider and program survey concerning DUI/DUID rehabilitation measures in Europe.
• Worldwide largest feedback study involving almost 8,000 participants of European driver rehabilitation measures from 9 countries.
• First inventory on quality management systems in driver rehabilitation.
• Evaluation tool for driver rehabilitation measures.

DRUID participants in WP6 conduct comprehensive analyses of the legal framework in the European countries with regard to their effects on combating DUI. A special focus is set on conditional driving license withdrawal as well as countermeasures and prevention. It is intended to identify "best practice" procedures to be recommended to the EU member states.

WP7 concentrates on dissemination and the development of guidelines. Especially information about medicines (and drugs) that are likely to affect driving performance and thus result in an increased potential risk of being involved in an accident, must be communicated to patients (drugs users, health care professionals) in a manner that ensures the information is fully understood. In order to improve patients’ (drug users’, health care professionals’) risk awareness, information leaflets, public campaigns and web-sites will be developed by using multimedia techniques. DRUID focuses on new ways to apply information and communication technologies (ICT) aiming to assure the use of modern knowledge in computerised prescribing and dispensing systems.

1 INTRODUCTION
The aim of reducing the number of victims in road traffic requires consideration of all facets of the traffic system. Besides road infrastructure and technical devices, the focus has to be laid on the performance of the driver. Whereas substantial progress has already been made in education and training, knowledge about the impact of psychoactive substances on traffic safety is limited. The scientific discussion is dominated by the problem of drink driving. A lot of knowledge about alcohol effects, the circumstances of drink driving, as well as about effective countermeasures, has been accumulated in the past. The result of these efforts is convincing: Albeit the alcohol in traffic problem is still virulent, its scope has substantially decreased in the EU Member States. But today other psychoactive substances – illegal drugs and medicines with impairing effects – affect road traffic safety to at least to the same extend: The reasons can be found in societal changes. On the one hand a new youth culture emerged searching for new experiences, including drug consumption; on the other hand our society changes into an older one with increasing consumption of medicines. Traffic safety has to deal with these problems against the background of exponentially increasing mobility.

Only a few surveys have been carried out in Europe as well as in Australia regarding the prevalence of drugs in the driving population (e.g. Krüger, 1995, Starmer, 1997). The prevalence rates are based on oral fluid samples from passenger car drivers and indicate similar results. About 1% took illicit drugs, primarily cannabis/stimulants, and about 4-6% took licit drugs, primarily stimulants, hypnotic or anxiolytic drugs, or drugs without impairing effect. Recent studies have been carried out in Denmark (Behrensдорff, 2001), the Netherlands and United Kingdom, the latter two studies were part of the project IMMORTAL of the EU 5th Framework Programme. Some of the studies also aim at enlightening the problem of an increased risk for driving while impaired, despite the fact that calculations of accident risk are subject to great uncertainties (Parliament of Victoria, 1996). These calculations indicate that, compared to that for sober drivers, the relative risk of being killed in a fatal accident is significantly increased for drug-impaired drivers, especially for drivers impaired both by drugs and alcohol.
In some countries a different approach has been taken to reveal the size of the problem. In Australia (Starmer, 1997), Belgium (Belgian Toxicology and Trauma Study Research Group, 1997), Spain (Rio, 1995) and Sweden (Törnros, 1997) drivers have been interviewed at rest areas and in emergency rooms about their drug consumption. Results indicate that 5-10% of the drivers admit using drugs “hazardous” to road safety, primarily benzodiazepines, and 3-5% of them admit using illicit drugs, primarily cannabis or amphetamines.

Thus, the knowledge concerning prevalence and risk of DUI of psychoactive substances is fragmentary. Neither the situation in each EU member country is known, nor is the information available, whether the problems and solutions can be generalised for other countries. The same holds true for legislative and preventive measures, established up to now. Some countries have introduced a zero tolerance law for illegal substances irrespective of the availability of the knowledge on impairing effects. Other countries pursue a clear impairment approach.

2 THE “DRUID” PROJECT
The European Integrated Project DRUID is a part of the 6th EU Framework Programme. It brings together 37 institutions from 18 European countries. It started in October 2006 and will end in October 2011.

DRUID understands itself as an integrative effort to reduce traffic safety risks caused by psychoactive substances. The objective of DRUID is to gain better knowledge of the various aspects of driving under the influence of drugs, alcohol and medicines and to offer scientific support to EU transport policy makers by suggesting guidelines and measures to combat impaired driving. The interest is to understand all facets of the problem: consumption, impairing effects, accident risk, detection, deterrence, rehabilitation, legislation and prevention aiming at the whole class of psychoactive substances (alcohol, drugs and medicines) and different subgroups and characteristics of consumers (patients, drug users, elderly, novice and young drivers etc.). This issue is substantially new and equates a milestone in this research field. Therefore DRUID opens the chance of a new and comprehensive approach to reduce the number of victims of traffic accidents.

The activities planned to achieve this ambitious aim are divided into seven DRUID work packages (WP). The WPs and their interdependencies are shown in Figure 1.
3 METHODOLOGY & EXPERIMENTAL STUDIES

In figure 1 WP1 “methodology and experimental studies” is placed in the centre of the “snowflake” indicating its key position within DRUID. The part “methodology” signifies the methodological framework which is developed to guarantee standardization and comparability between the multiple studies and thus presentation of comprehensive and across-WP results. This especially holds true for the experimental studies, which are conducted in WP1 and for the epidemiological studies, which are conducted in WP2. The methodological framework serves as basis to make risk thresholds from experiments and relative risk estimations from epidemiological studies comparable. The main idea of this new approach is to use alcohol as reference. Up to now alcohol is the only psychoactive substance that is well investigated; we have detailed knowledge about the effects of alcohol on driving and accident risk. In fact alcohol is the only substance for which legal limits are defined Europe-wide. In most European countries people are allowed to drive a car with a BAC up to 0.05%. This value is a risk threshold indicating that the risk of unsafe driving is tolerated up to this level. BAC that exceed 0.05% are associated with intolerable high risk. This knowledge and conventions are pragmatically utilized in the methodological framework and serve as reference for other psychoactive substances. The framework was presented as a deliverable and is available on the DRUID-website.

In addition to the methodological part experimental studies are conducted in WP1. Partners from seven European countries conduct simulator and on-the-road studies. The experiments assess the effects of single and combined psychoactive substances on driving performance, including illicit drugs as well as medicines. Alcohol is used as reference in every experiment. Standardized driving tests, measurements and analysing methods are developed and guarantee a maximum of comparability between the different studies. The experiments provide important information for the development of risk thresholds for psychoactive substances (e.g. MDMA). This information refers on the one hand on risk functions depending on different dosage levels and on the other hand on risk functions depending on blood concentration rates of the substance under study.
These findings are not only decisive for recommendations of risk thresholds, which is one of the main objectives of DRUID, but also serve as input for other WPs by providing an (additional) empirical basis e.g. for classification of medicines (WP4) or dissemination activities (WP7).

4 EPIDEMIOLOGY

The main aim of WP2 is to assess the situation in Europe regarding the prevalence of psychoactive substances in drivers in traffic in general and in drivers who have been killed/injured in traffic accidents. Additionally an overview of the prevalence in general drug consumption in Europe is presented and different studies to examine the characteristics of impaired drivers are conducted, including the question of accident responsibility. The prevalence data is used for relative risk estimations of accident involvement for drivers impaired by psychoactive substances.

The assessment of prevalence data in general traffic is a big challenge, due to legal (e.g. only voluntary participation of subjects), methodological (e.g. representativeness of data) and practical (e.g. organization of co-operations with the police) obstacles. Within DRUID roadside surveys are conducted in 13 countries, all using the same methodological standards (e.g. same sample periods) to guarantee national representativeness and comparability between the different studies. Oral fluid samples and/or blood samples are taken from randomly selected drivers and are analyzed in toxicological laboratories which also agreed on special DRUID-standards. Up to now about 50,000 samples have been collected.

Samples from injured and/or killed drivers in the same period and geographical area as the roadside surveys are analysed to gain the prevalence of psychoactive substances among accident involved drivers. These “hospital studies” are conducted in six countries. The challenge of conducting such studies is in some countries even bigger than for roadside surveys, because the scientific work has to be integrated into the daily work of the hospital staff and strict ethical regulations (e.g. necessity of a written consent from the patient) have to be followed. The specimen under study is whole blood. The same laboratories as in the roadside surveys do the toxicological analyses of the hospital samples. In total, about 2,500 samples have been collected.

Based on linkage between “cases” (samples from roadside surveys) and “controls’ (samples from hospital studies) relative risk estimates for traffic accident involvement of drivers impaired by alcohol and/or various psychoactive substances are calculated and will form a basis for recommendations for risk thresholds (WP1).

In addition to the mentioned challenges in these studies an unforeseen problem aroused: For some psychoactive substances the conversion factors to convert the concentration rate from one body fluid to another are not known yet. This means that a “simple” conversion from blood to saliva or vice versa is not possible. Therefore within DRUID a working group (WG) “conversion factors” was established to address the problem of comparability of substance concentrations measured in saliva, whole blood and plasma. In co-operation with WG “toxicology”, which is the forum of all participating toxicological laboratories, the WG “conversion factors” will contribute to develop methods to solve this problem. A satisfying solution of this problem is especially important for data integration of WP1 and WP2.

5 ENFORCEMENT

WP3 aims at improving the possibilities of detecting drug driving in Europe. Therefore WP3 partners conduct a large-scale scientific and practical evaluation, under realistic enforcement conditions, of on-site oral fluid screening devices for the detection of impairing psychoactive substances (other than alcohol) in drivers.
Oral fluid screening devices are tested according to a fixed protocol by the police forces in eight countries under operation field conditions. The practical evaluation is directed to functional and user (drivers, police, and judicial system) requirements, comprising the willingness of drivers to co-operate, time consumption, user friendliness and material costs. At the end of the testing periods 200 tests with each device are executed and evaluated.

The scientific evaluation of oral fluid screening devices and other methods (checklists of signs of impairment) for the detection of drug-impaired drivers is conducted in three countries. The scientific evaluation focuses on the reliability (i.e. sensitivity, specificity, accuracy) of the instruments.

The outcome of the practical and scientific evaluation is an input to cost-benefit analysis of drug-driving enforcement by the police. Two cost-benefit analysis models are tested taking into account the costs of accidents, fatalities, injuries and material damage, the effects of enforcement on these, the value of security perceived by other road users, the costs of police and road user time, the costs of vehicles, fuel, devices and equipment, of laboratory analyses and the costs of the judicial system.

6 CLASSIFICATION

A large proportion of the population habitually drives while taking medicinal drugs. Some of these medicines can deteriorate psychomotor performance, which can affect a person’s ability to drive safely.

WP4 “classification” has four objectives:

- To review the existing classification/categorisation systems and labelling systems regarding medicinal drugs and driving.
- To propose and agree on the criteria and the methodology for the establishment of a European classification/categorisation system and labelling system of medicinal drugs and driving.
- To develop of a methodology to continuously update the classification/categorisation system and labelling system of medicinal drugs and driving.
- To propose a classification/categorisation system for the relevant therapeutic groups of medicines available in the market.

These activities are done in close co-operation with the relevant international agencies and organisations, like EMEA, TIAFT, FERSI, the Pompidou Group or DG TREN Working Group on Alcohol, Drugs, Medicines and Driving.

WP4 will have an output both for physicians/pharmacists and other health professionals, as well as the patients taking these medicinal drugs, through two major actions: categorization of the medicinal drugs on driving ability, and the proposal of appropriate labelling systems regarding medicinal drugs and driving.

7 REHABILITATION

Suspension of driving license, fines and/or imprisonment of drivers having committed serious offences or accidents while being impaired due to psychoactive substances do not necessarily result in behavioural change. Thus, so-called rehabilitation measures have been developed in order to avoid re-offences in traffic.

WP5 “rehabilitation” aims to

- review existing rehabilitation measures and assessment procedures applied in the EU
- identify subtypes of DUI/DUID offenders
- create uniform criteria for the assignment of offenders to the appropriate programs
- analyse reasons for recidivism after participation in rehabilitation measures
- express quality standards for successful interventions and
• develop an evaluation instrument for best practices.

All research findings are consolidated in order to achieve the common purpose of providing fundamentals for establishing adequate and effective rehabilitation measures throughout the Member States.

The basic results from previous worldwide research are elaborated via literature analysis in all fields of interest. Data collection conducted in the member states by means of especially designed questionnaires serve to provide a comprehensive overview over existing rehabilitation approaches. Further questionnaires are handed out to participants of rehabilitation programs to discover the relevant determinants of behaviour change. Telephone interviews are used for in-depth-analysis on reasons for recidivism. Main elements of quality assurance are identified by additional questionnaires and expert hearings. Workshops in member states without driver rehabilitation approaches are conducted to disseminate the most important findings.

WP5 is the only work package that has already finished its work. The work package results are presented in five deliverables available on the DRUID-website. The main results might be summed up as follows:

State of the art
• Implementation and application concepts and practice of DUI/DUID rehabilitation in the EU varies significantly, there are many national peculiarities.
• Currently at least 47 providers in 12 European countries offer driver rehabilitation (DR) services on a regular base.
• In total 87 DR programmes are in use, 53 for DUI offenders, 21 for DUID offenders and 13 for mixed groups.
• DR programmes show an average recidivism reduction rate of 45.5%, but considerable deviations are observable.

Good practice
• Risk factors for DUI recidivism:
  • high BAC level or breath test refusal
  • prior DUI offences and consequently longer suspension period
  • habitual drinking pattern and periods of increased alcohol tolerance
  • denial of alcohol-related health problems
  • unrealistic self-perception and self-reflection

• Quality Management in DR services:
  • Quality management (QM) is necessary to create and increase confidence of legislators, authorities, individuals and the public.
  • Current degrees of QM implementation range from voluntary applied QM elements over QM systems up to sophisticated national QM standards.
  • WP5 defined QM criteria and developed a decision-tree to establish and evaluate QM systems in DR services on a national, provider and programme level.

• Feedback study (N= 7,889 participants of DR programmes from 9 European Countries):
  • DR interventions are highly accepted and positively evaluated by DUI and DUID offenders.
  • The concepts of DR group courses seem to be adequate for the majority of offenders.
• DUI and DUID course participants can successfully proceed through all stages of change.
• No long-term conclusions regarding recidivism can be drawn.

• **Driver Rehabilitation Evaluation Tool (DRET):**
  • A systematic and comprehensive check/evaluation instrument for planned or already existing DR programmes and systems has been developed.
  • DRET is a service instrument for different user groups who are working in the field of DR.
  • DRET is a tool to find out whether all necessary elements regarding the establishment and operation of DR measures are included or whether there are any gaps or weak points which need improvements.

**Recommendations**

• Rehabilitation options/needs for different offender types

<table>
<thead>
<tr>
<th>Non addicts</th>
<th>DUI offenders</th>
<th>DUID offenders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addicts</td>
<td>DR alcohol programme</td>
<td>DR drug programme</td>
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<tr>
<td></td>
<td>Addiction treatment alcohol</td>
<td>Addiction treatment drugs</td>
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• Distinctions between DUI and DUID offender as well as addicts and non-addicts are important.
• Alcohol ignition interlock can be an additional option for DUI offenders but they cannot substitute DR course or treatment, as they are only effective as long as they are installed.

• **Linkage between DR interventions and addiction treatment**
  • Information exchange between experts from addiction treatment and DR interventions should be improved in order to advance driver rehabilitation for the entire group of DUI/DUID drivers.
  • Some traffic safety/driving license/intoxicated driving related modules should be integrated in addiction treatment.

• **Assignment to driver rehabilitation**
  • Participation in DR should be legally regulated and obligatory in order to systematically bring high-risk offenders to driver rehabilitation.
  • Assignment procedures should be defined and formal criteria should be fixed which directly lead to DR participation.
  • Driver assessment prior to DR as a decision tool - in order to select the adequate intervention/treatment - should be carried out in case of suspicion of addiction and high recidivism risk (BAC-level above 1.6‰, re-offending within 5 years, refusal of alcohol test).
  • Regarding DUID offenders, driver assessment should always be carried out, until the threshold values question is solved.

• **Content-related requirements of DR**
  • European standard group interventions can be recommended as a good practice example for non-addicted DUI/DUID offenders.
• Single DR interventions should be provided for offenders in/with special conditions.

• Quality related requirements of DR
  • In order to guarantee the necessary service quality in DR a national QM body should be installed which has an independent, authoritative position to execute the operative QM tasks in DR.
  • QM requirements should be established on a legal base in order to provide uniform QM standards on DR.

• European initiative
  • WP5 strongly supports a preventive DR concept which is compatible with the overall objective of mobility of European citizens without endangering traffic safety.
  • The European Commission would be good advised to support DR. A basic statement could be incorporated in the EU Road Safety Act saying: “DR for DUI/DUID offenders should be an integrated part of a comprehensive countermeasure system against intoxicated driving in Europe.”
  • In a next working step, European guidelines for legally regulated driver rehabilitation systems and procedures should be established taking the WP5 results into account.

8 WITHDRAWAL
The European Council Directive of 29 July 1991 on Driving Licenses calls upon all Member States to provide regulations that prevent dangers in traffic safety resulting from alcohol- and drug-impaired drivers. The implementation of this directive in the different national laws implicated that the legal systems show substantial differences. Thus WP6 “withdrawal” aims to collect information regarding legal issues and practices of license withdrawal and reinstatement in the European countries. The different issues concerning criminal sanctions and administrative consequences are assessed and compared, intending to evaluate the effects of the various strategies. An exploratory focus is lay on conditional withdrawal and driving licenses with restrictions, e.g. while under medication treatment or concerning technical systems like ignition interlocks. These analyses serve to gain insight into methods to reduce impaired driving while preserving the greatest mobility and at the same time reducing the accident risk while impaired.

WP6 adapts the questionnaires which were sent out in 1998 and 2001 by the Pompidou Group to 24 European countries. The results will be updated by sharpening the questionnaires with respect to withdrawal and reinstatement issues. Additional specifications regarding technical measures for secondary prevention are included. The redesigned version is send to legislative administrators of all Member States and selected non-member states in order to collect and evaluate data on best practices. Interviews with country experts serve to complete information. Workshops are arranged and the evaluated results are presented and discussed by representatives and experts of different countries.

The integration of all the WP6-findings and the results of WP5 “rehabilitation” and WP1, Task 1.3 “recommendation of thresholds” will lead to the development of prototypical solutions and comprehensive recommendations for a catalog of legal countermeasures against DUI/DUID in Europe and will provide reliable data for the orientation of administrators, politicians and researchers.
9 DISSEMINATION & GUIDELINES
The aim of this WP7 “dissemination and guidelines” is to
- review existing DUI campaigns.
- develop guidelines for physician and pharmacists to select the least impairing medicine.
- develop information materials aimed at the general public, drivers as patients, and health care professionals.
- evaluate practice guidelines and protocols in day-by-day medical and pharmaceutical practice.

Several methods are used for investigating the impact of existing campaigns such as searches of the scientific literature and consultation of experts through various international organisations.

The existing medical guidelines for assessing fitness to drive are evaluated on the basis of legal outcomes in the event of accidents occurring after a positive decision from a physician’s side. After reviewing some best practices a proposal is made for improving the procedures for assessing fitness to drive within the framework of Council Directive 91/439/EEC (on driving licences).

Various documents and brochures for dissemination of information will be addressed to the general public, drivers as patients with a focus on younger drivers, physicians and pharmacists, policy makers and other public bodies.

The implementation of new practice guidelines and protocols for medical and pharmaceutical care are investigated after baseline measurements in the Netherlands, Belgium, Spain and Germany. Specific attention is given to opportunities of using Information and Communication Technology (ICT) in the computerised information systems that physicians and pharmacists use in their daily practice.

The outcomes of all tasks in this work package will offer opportunities to evaluate the effectiveness of risk communication to patients and drug consumers regarding psychoactive substances affecting driving performance. By using the categorisation system developed in WP4 and by investigating the patients’ and health care providers’ satisfaction the outcomes of the implementation can be further defined.

10 POTENTIAL IMPACT OF DRUID PROJECT
Impaired driving is one of the major causes of road accidents. The integrated project DRUID aims to combat the scourge of drink-driving and find answers to the question of the use of drugs or medicines that affect people’s ability to drive safely. To achieve this aim DRUID tries to consider all facets of the problem: impairing effects, consumption, accident risk, detection, deterrence, rehabilitation, legislation and prevention.

Each of the seven DRUID work packages is dedicated to at least one of these aspects. For example WP1 examines the correlations between alcohol/drug/medicine consumption and driving performance, resulting in valuable information in regard of recommendations of risk thresholds for psychoactive substances. In WP2 prevalence data on consumption of alcohol, drugs and medicine in the driving population is gathered. It is the first time that such data – collected according to a uniform study protocol – will be available for many European countries. The same holds true for relative risk estimations, which will be derived from the case-control studies in this WP. Detection of drug drivers is an important aspect in the interaction of punishment, rehabilitation, and prevention. Therefore the activities in WP3 make a valuable contribution towards optimizing and harmonizing the daily work of the police in regard of detecting drug driving by using oral fluid screening devices. The classification and labelling system for medicinal drugs, which is planned in WP4, contributes...
to improve the exercise of rights and duties of patients and health professions and therefore conduces to prevention. Along the same lines is the work of WP7. Adequate information of all relevant groups is mandatory to bridge the gap between scientific results and implementation of these results in daily life. Rehabilitation in terms of driver rehabilitation is on the one hand the end of chain of drink and/or drug driving and on the other hand DR is an important and successful measure to prevent future drug offences. The results and recommendations of WP5 clearly show the work that still has to be done to achieve harmonized DR services with high quality standards all over Europe. Differences between countries and requirements for harmonization in regard of legal regulations are detected in WP6 as well. The knowledge of the different legal systems and their impact on consumption of psychoactive substances and driving is a pre-condition to improve or develop e.g. risk thresholds.

This multidisciplinary and multitasking work from researchers all over Europe establishes a network that is a good DRUID result in itself. The close co-operation between WPs and scientists from different countries promotes mutual understanding and thus sets the stage for the development and establishment of common standards, harmonized legislation and regulations.

DRUID as an integrated project not only brings together most prominent DUl researchers throughout Europe but also incorporates the concerned groups, like drug consumers, patients, health professionals, policemen etc. in Europe. Solely the roadside surveys conducted in WP2 “mobilise” thousands of drivers and hundreds of policemen all over Europe and evoke public interest and discussions. Therefore DRUID itself can be considered as a large prevention program in the sense of drawing attention to a major traffic safety problem.

The impact of DRUID in regard of supporting European transport policy makers and even stakeholders from overseas is substantial. In the daily work with national and international researchers, stakeholders and politicians the recognition and relevance of DRUID can already be noticed. In Germany for example important political decisions are postponed, because the responsible persons want to integrate the DRUID results into their discussions and decisions.

Summing up this impact DRUID will

• improve the knowledge on the effects of alcohol, illicit drugs and medicines on fitness to drive
• give new insights to the real degree of impairment caused by psychoactive substances and their actual impact on road safety
• generate recommendations for the definition of analytical and risk thresholds
• recommend “good practice” for detection and training measures for road traffic police allowing a legal monitoring of drivers
• establish an appropriate classification system of medicines affecting driving ability, give recommendations for its implementation and create a framework to position medicines according to a labelling system
• evaluate the efficiency of strategies of prevention, penalisation and rehabilitation, considering the difficulties of appropriate evaluation strategies for combined substance use and recommend “good practice”
• define strategies of driving bans, combining the road safety objectives with the individual’s need for mobility
• define the responsibility of health care professionals for patients consuming psychoactive substances and their impact on road safety, elaborate guidelines and make information available and applicable for all European countries.

11 ACKNOWLEDGEMENT
The above sections presented a brief description of the work carried out in the project. These activities are the result of close collaboration and efforts of numerous European partners.

REFERENCES
IMMORTAL D-R4-2 (in press)
Integrated system for safe transportation of children to school
“SAFEWAY2SCHOOL”

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ABSTRACT
Between 1994 and 2001, 361 children were injured or killed during transportation to/from their school in Sweden, whereas 455 were killed or injured in Austria only in 2007 and 97 were killed in Italy in 2005. In a single school bus accident in Greece in 2003, 20 children lost their lives. Different as the above numbers may be, they all tell us one thing: Crashes involving school buses and crashes involving children travelling from/to school are far from negligible and require further efforts to be drastically reduced.

SAFEWAY2SCHOOL is an EU-project funded by the 7th Framework launched in September 2009. The aim is to design, develop, integrate and evaluate technologies for providing a holistic and safe transportation service for children, from their home door to the school door and vice versa, encompassing tools, services and training for all key actors in the relevant transportation chain. These include optimal route planning and rerouting for school buses to maximize safety, on-board safety applications (i.e. for speed control and seat belts), “intelligent” bus stops, effective warning and information systems for bus drivers, children, parents and the surrounding traffic; as well as training schemes for all actors. The project innovative systems, services and training schemes will be tested in 4 sites Europe-wide, including north (Sweden), central (Austria), south (Italy) and eastern (Poland) Europe; to evaluate their usability, efficiency, user acceptance and market viability; taking into account the variety in children’s transportation to/from school systems among the different European regions as well as key cultural and socio-economic aspects.

In order to get an indicative view of the SAFEWAY2SCHOOL system and the basic idea behind, a pre-pilot using an on board system for navigation, route guidance, information about children and communication between buses, bus stop and child has been performed. The pre-pilot utilised off-the-shelf technology, in order to create a driver support system that raises the level of routines in school transportation and facilitates communication between the drivers and the children. Two buses, driven by seven drivers were equipped with the system, comprising data for 130 children. Moreover, two bus stops were equipped with flashing lights, triggered by radio transmitters that the children wore. The evaluations of the system showed that it does raise the level of routines and allow the drivers to supervise the children, in order to take action in case of an emergency. All system modules were frequently used have been evaluated as useful from all users. Children reported feeling more secure with the system running and experienced less stress as a benefit from it. The average speed of other cars was significantly reduced by the flashing bus stops. With a cost of 0.5-2 SEK per school day and child, the system could prevent fatal injuries in school transportation, generating monetary benefits on a societal level.
1 INTRODUCTION
Even though protecting the children – one of the most vulnerable transport system’s users – is of great importance for all societies, bus transport to school is a highly underinvested area in many EU-countries. School transportation by bus is not just about using the school bus, but it should be considered from a door to door perspective. Unfortunately, crash statistics often lack the school bus transport accidents with children as vulnerable road users, i.e. before the bus arrives or after it departs, and therefore fails to put light onto the situation and falsely make bus transport to school look less severe. A very thorough investigation by the Swedish national road administration, done in 2004, shows that the highest risk for a child to be injured or killed in a school bus transportation related crash is as a vulnerable road user (A Anund et al., 2003). The most critical situation is when getting to and from the bus stop and while waiting at the bus stop. However, the Swedish study also underestimates the problem, since it only covers the accidents where a bus and a child were involved, leaving out accidents where children were hit by, for example, a passenger car. Furthermore, in most countries there are no systematic systems for school bus route guidance or route planning. This is important not only as a driver support system, but also to optimize the bus route to cut CO2 emissions. There is a need for a system that supports the driver of the bus, in order to know where to go, where the bus stops are situated and which children are supposed to enter or exit. Compared to other types of transportation, for which you often know or have the possibility to know where the goods are, there is a lack of control/information about the child when going by bus transportation to school. In addition, it is important to increase the visibility and awareness for other road users (i.e. car driver), with an EU-unified marking and signing traffic participants, to make them decrease speed or even stop when passing a school bus. Increasing safety and security of school bus transports can make more children and their parents feel confident to use the school or public buses instead of a passenger car, cutting CO2 emissions even further.

2 THE CONCEPT
SAFEWAY2SCHOOL is an EU-project funded by the 7th Framework launched in September 2009, and has 36 months duration. The total budget is 3,7€ millions. The aim is to design, develop, integrate and evaluate technologies for providing a holistic and safe transportation service for children, from their home door to the school door and vice versa, encompassing tools, services and training for all key actors in the relevant transportation chain. These include optimal route planning and rerouting for school buses to maximize safety, on-board safety applications (i.e. for speed control and seat belts), “intelligent” bus stops, effective warning and information systems for bus drivers, children, parents and the surrounding traffic; as well as training schemes for all actors. The project innovative systems, services and training schemes will be tested in 4 sites Europewide, including north (Sweden), central (Austria), south (Italy) and eastern (Poland) Europe; to evaluate their usability, efficiency, user acceptance and market viability; taking into account the variety in children’s transportation to/from school systems among the different European regions as well as key cultural and socio-economic aspects. The SAFEWAY2SCHOOL concept is based on a holistic approach with a door to door perspective, that is in detail presented in Fel! Hittar inte referenskälla...This holistic approach includes all the possible steps that can be involved in the school transportation chain and aims in optimizing the school transportation safety and efficiency
A Holistic approach from door to door perspective

Figure 1: The SAFEWAY2SCHOOL approach from door to door perspective.

The project follows a holistic approach from the children door to door perspective. Use cases will be defined at the beginning of the project by collecting crash data through available databases from European countries. To ensure that children follow a safe way from home to the bus stop and from bus to school, communication has to be established between children/bus stop and road users. The project’s scope include both software and hardware development. A new sign for school transport will be developed and displayed on buses that assure school transport. An HMI profile in relation to all situations will be developed – from support system for the bus driver to the arrival notification, training schemes and municipality’s office.

3 PROJECT OBJECTIVES

More specifically, SAFEWAY2SCHOOL aims at:

- Developing optimal route planning for school buses, to guide them through areas of low traffic, avoiding black spots.
- Developing optimal real-time route guidance, taking into account dynamic traffic data, as well as the arrival and estimated arrival of children at the bus stops.
- Developing “intelligent” bus stops that understand the position of children and school buses and transmit relevant info and warnings to both actors.
- Developing a seamless, reliable and secure system of school bus position tracking and monitoring and a parents’ notification system, when children are on-board the school bus.
- Integrating safety enhancement applications regarding speed monitoring and safety belt usage for the school bus, while travelling.
- Developing warning systems for surrounding vehicles on the existence of stopped school buses or/and children waiting/entering/exiting.
- Developing appropriate training schemes for school bus drivers, children, parents and all drivers, for optimal use of the developed systems and children safety enhancement in general.
Performing socio-economic analysis, to identify the optimal business plans, legal schemes and organizational incentives for rapid adoption and wide market penetration of SAFEWAY2SCHOOL system.

Target Groups of the project include:
- School bus drivers.
- Students/children: 6-9, 10-12 and 13-16 years old, with and without disabilities, when they may travel alone from/to school bus, although some applications (e.g. safety belt use) are for all ages.
- Families of the children.
- Infrastructure (i.e. bus stops or bus fleet operators).
- Car manufacturers (OEM’s).
- Authorities (legislators, municipal and school authorities).
- All drivers (i.e. of surrounding traffic vehicles).

The project aims to combine a wide range of technologies on localization, route planning, route guidance, vehicle to infrastructure and on-board systems and sensors, short-range and GPRS communications, etc; in order to solve holistically the issue of safe transportation of children from their door to the school and vice-versa.

4 SAFEWAY2SCHOOL ARCHITECTURE
The SAFEWAY2SCHOOL architecture aims at the aforementioned holistic approach. In order to have a safe and secure transport for the children to and from school, we need to focus not only on the trip inside the bus, but also on safety criteria’s for the way to and from the bus stop, the bus stop and how to make sure passing vehicles reduce their speed and are more aware of children around the bus stop or bus when passing. An also important aspect is the training of the bus driver and the children. In Fel! Hittar inte referenskälla., an overall view of the SAEWAY2SCHOOL system architecture is presented, that gives a first idea of the different systems involved and stakeholders’ interests in the project.

Figure 2: Draft system architecture for SAFEWAY2SCHOOL.
This holistic approach includes strategic, tactical and operative systems starting with an inventory tool in which safety and security criteria will be implemented. The outcome of this inventory will be used as an input when making the route but also to be taken into account during rerouting. The basic idea is to make sure the route is not using unsafe/non-secure bus stops but also to make sure that the children are not in danger when going to and from the bus stop. On the strategic level, there will be also training schemes for both children/parents and bus drivers. On the tactical level, there are systems for rerouting depending not only on traffic situation, but also on information about the child, for instance, children not using the bus a given day. The rerouting system will use information from children via transmitters, by mobile phones or by web applications. Their parents can log into the system and update the information. Traffic information will be updated to the system through a web application. The system will take all information into account and schedule a new route visualised by the driver decision support system (DSS). This information will also be sent to the children/parents mobile phones as an arrival notification. Child specific or traffic specific information will be send to the bus through a web application. The DSS will be connected to a server that will handle the information and the rerouting parts.

Moreover, on the operative level, there is a system targeting to raise the alertness of road users on children while being on their way to and from the bus stop or waiting at the bus stop. The system will only send information to the passing vehicles when there are children around. This will be achieved through the use of transmitters tagged in the children bags and warning signals (visual / audio) at the bus stop. The signing on the bus is also included and a module will be developed as well that, with the help of the sign, will warn drivers on potential risky situation in front. The sign will start and stop automatically administered by the route guidance system and the GPS position of the bus stop.

Finally, the project will provide guidelines for authorities and give input for training courses for children, parents, bus drivers and other relevant stakeholders. Recommendations for policy and standardisation of school transportation through European members’ countries will be delivered within the project. In addition, a user forum and workshops will support dissemination of the project and provide the project with valuable feedback from stakeholders.

5 PILOTS AND TEST SITES

The largest effort in the project will be spent to test modules, services and training schemes in 4 sites in Europe: Sweden, Austria, Italy and Poland, see Fel! Hittar inte referenskälla.. During the verification pilots, the systems will be evaluated on their usability, efficiency, user acceptance and market viability; taking into account the very different children’s transportation to/from school systems across the different European regions. The pilots will utilise off-the-shelf technology, in order to evaluate a driver support system that raises the level of routines in school transportation and facilitates communication between the drivers and the children.
Figure 3: Pilot sites within SAFEWAY2SCHOOL, the buses represent the pilot sites and countries in colour are Consortium members’ representation within the project.

The pilot sites will implement different parts of the SAFEWAY2SCHOOL concept and the system and concept will be evaluated. The aim is to run experiments that include not only one single part, but several parts in order to evaluate the effect of the holistic approach. All pilot experiments will be based on the same technical solutions, but multiple systems will be implemented, in order to run the experiments in parallel. The SAFEWAY2SCHOOL is addressed to different stakeholders such as: municipalities, children and parents, school bus drivers and road uses and in each site there will be a focus on two or more of the stakeholders.

In more detail:

In Austria the pilot will focus on car drivers which approach a stopped bus when children are entering/exiting the bus as well as on results of the training of safe routines addressing bus drivers and children. Based on the legal regulation concerning the obligation to stop behind the school bus, the pilot should highlight the real situation and deliver results for further modifications by means of awareness rising. Therefore, the new sign, which indicates that children are getting on or off the bus and which will be designed and tested for comprehensibility during the project, will be fixed to buses. The aim of the pilot will be to test the effectiveness of this sign in real life. Therefore the speed of passing cars will be recorded by means of radar equipment, which will also be fixed to the buses. Furthermore, data from visual observations will be used to consider several factors for the analysis, e.g. the behaviour of the drivers, the behaviour of the children getting on/off the bus, the number of children, age of the children, etc. Several other factors contributing to potential conflict
situations between travellers as pedestrians and vehicle flow in the zone of the bus stop, will be taken into account for the pilot (e.g. surrounding infrastructure, like pedestrian crossings or if there is a bus stopping bay or not; density of traffic, e.g. congested urban centre or bus stop in a small village; etc.). The pilot in Austria will at least run for three month with at least 4 equipped buses (2 with signs and radars and 2 without signs but radars). Data will be gathered when the bus stops at preselected bus stops. Visual observers which will log the behaviour of pupils, etc., will be present once a week. It is planned to develop and respectively to use the WP5 acoustic signal to catch the attention of the children while they are waiting at the bus stop and the bus is approaching. Two aims may be pursued: the interaction between the alertness of the children and the cars stopping behind the car and/or reducing their speed. Secondly, the acoustic signal aims at a kind of conditioning of children to realize the danger based on the approaching bus and passing cars. For statistical comparison data from buses with the new sign will be compared to buses without the new sign.

The Italian pilot will focus on school transportation through both special and public buses (one bus of each category), serving urban and extra-urban areas in the surrounding of Reggio Emilia area. The school transportation service is provided by a private company, working as a subcontractor of the municipality.

The basic requirements for the pilot site will be to equip two buses, differing in:

Public vs. Special vehicle. This is particularly relevant as to bus stops: public services generally stop at permanent and signalled stop areas, whereas special buses change their stops according to the location of children’s homes.

- Served areas (urban vs. extraurban).
- Presence of adult assistants: an adult supports the bus driver in managing the children aboard the bus on special buses, whereas such a person is usually not present on public buses.

Disabled students will also be involved in the pilot’s activity, regardless of the case taken into account, as this issue crosses all of the other pilot’s concerns.

The Italian pilot will be specifically focused on routing optimization by rerouting and on signalling both with the new sign on the buses and with signing at the bus stop. Moreover, as a local peculiarity, the role of adult on-bus assistants will be taken into account. A set of served areas will be selected as relevant for route optimization issues, differentiating the factors possibly affecting the timeliness and quality of the service: for instance, areas encompassing frequently jammed urban and extra-urban roads will be considered. Isolated and occasional stops, especially in extra-urban isolated areas, will be considered for special buses.

The pilot in Poland should aim at car drivers who pass a stopped bus when children are getting on or off the bus as well as the effect of the training of safe routines for bus drivers and children. In addition an experiment with car drivers will be performed studying the driver’s visual pattern by measuring eye movements when approaching an “intelligent” bus stop.

Based on the legal regulations concerning the obligation of a car driver to act with special attention and if necessary to stop behind the school bus, the pilot should highlight the real situation and deliver results for further modifications by means of awareness raising. Therefore a new sign which indicates that children are getting on or off the bus and which will be designed and tested for comprehensibility during the project, will be fixed to buses. The aim of the pilot will be to test the effectiveness of this sign in real life. Therefore the speed of passing cars will be recorded by means of radar equipment installed around the bus stops. Furthermore, data from visual observations will be used to consider several factors for the analysis, e.g. the behaviour of the drivers, the behaviour of the children getting on/off the bus, the number of children, their age, etc. Other factors contributing to potential conflict
situations among all road users, such as pedestrians and vehicle flow in the zone of the bus stop, will be taken into account for the pilot (e.g. surrounding infrastructure like pedestrian crossings or if there is a bus stopping bay or not; density of traffic). The pilot in Poland should run for at least three month with 4 equipped buses (2 with signs and 2 without signs) and bus drivers using the buses will be trained in safe routines when entering/exiting and waiting or walking to/from the bus stop. Data will be gathered when the bus stops at earlier selected bus stops equipped with “intelligent” bus stops. Visual observers which will log the behaviour of pupils etc. will be present once a week at the site.

It is also planned to develop respectively to use an available acoustic signal to catch the attention of the children while they are waiting at the bus stop and the bus is approaching (for this activity it is necessary to have an approval from the Ministry of Transport). Also the bus may send an acoustic signal during getting on/off of children. Two aims may be pursued: the interaction between the alertness of the children and the cars slowing down / stopping behind the bus. The acoustic signal aims at children to realize the danger based on the approaching bus and passing cars. For statistical comparison data from buses with the new sign will be compared to buses without the new sign.

The Swedish pilot will focus on school transportation by both special and public buses. The focus is two folded: one is on routing and rerouting using a real time web based application for rerouting. The route and stop for entering and exiting is decided using the criteria’s for safe way to bus stop and done with the help of the tools developed in WP 3. The pilot will also focus on evaluation of signing on the bus and in the infrastructure. The test site will include two different areas: one in the northern part of Sweden and one in the southern part. In both areas children with disabilities will be included. In total 4 buses will be used; 2 special purchased buses and 2 buses for public transport will be used for rerouting and signing. In total more than 100 children will be travelling by those. The bus sign will be used at least on those buses, the infrastructure signing will be installed in the same area as those buses are running. Additionally, the children will be informed and trained on how to behave when going by school bus. The evaluation of this part will be done as before – after study and cover the usability area, safety and security aspects for children and road users, but also effects in terms of speed and drivers gaze in relation to the bus/infrastructure signing.

6 PRE-PILOT IN THE MUNICIPALITY OF KRISTIANSTAD

Around 400,000 children go to school by school bus in Sweden every day. Crash statistics show that the level of safety in the school bus system generally is high (Anund, Larsson, & Falkmer, 2003; Larsson, 2008), despite the fact that one or two children will be fatally injured per annum. The most risky situation is when the child is outside the bus entering or exiting, lack of routines being the major cause.

The present pre-pilot utilized off-the-shelf technology, in order to evaluate a driver support system that raises the level of routines in school transportation and facilitates communication between drivers and children(Anund, Renner, Falkmer, & Waara, 2009). Based on a door-to-door perspective, the driver support system comprises navigation systems concerning bus stops and children, gathering and sharing further information about each and every child. The buses were equipped with communication devices to be used at bus stops, seat belt usage detection systems and camera surveillance systems, both inside and outside the bus. In addition, educational sessions and training for the drivers, as well as for the children, were carried out.

Based on a literature review, a Workshop was conducted with invited experts in the field of school transportation. The outcome of these two activities led to the choice of the components for the driver support system. Two buses were equipped with the system during 2008, collecting data for 130 children, and two bus stops were equipped with flashing lights,
triggered by radio transmitters that the children wore. These transmitters also triggered the driver support system. Among the seven drivers that participated in the pre-pilot, two were the regular school bus drivers of that route, while the other five were school bus drivers that realised other routes. The evaluations of the system were supplemented, from the qualitative perspective, by interviews, focus group interviews and diary notes. In addition, speed information was measured before and after the implementation of the flashing bus stop systems and a cost benefit analysis was done.

The drivers’ experience of the system confirmed the assumption that the driver support system does, in fact, raise the level of routines and that the technical solutions allow the drivers to survey the children in order to take action in case of an emergency. The diary reports showed that the different modules within the driver support system have been evaluated as useful and were frequently used. It may, however, be noted that several drivers paid more attention to their role as a “driver of the bus”, rather than as being an important link in the door-to-door transportation perspective of school children. The features of the system that these drivers criticised were the ones that “interfered” with their working environment while driving. The fact that they did not take into account, is that the system basically exists to support safe and secure transportation for the children. Some drivers experienced incorrect input data to the system, regarding routes, bus stops and children and this contributed negatively to their general view on the system. The children reported feeling more secure with the system and experiencing less stress as a benefit of it, especially when they were on their way to the bus, since they knew that the system was triggered when they were in the vicinity of the bus stop. The children have, however, not experienced increased level of routines. The average speed of cars has significantly been reduced by the flashing bus stops. Given that a full scale system would totally eliminate the type of fatal injuries to school children that occurred over the years 1994–2006, the cost-benefit analysis showed that the implementation of the system in all school transports may render costs ranging from 120,000–425,000 SEK/school day or 0.5–2 SEK per school day and child and still generate monetary benefits on a societal level.

7 CONCLUSIONS
Based on the experience from a pre-pilot, in the Swedish municipality Kristianstad, the next step towards safe and secure children transportation to/from school will be undertaken by the SAFEWAY2SCHOOL project. The pre-pilot showed the importance of a holistic approach including all intermediate steps from a door to door perspective. Therefore, SAFEWAY2SCHOOL targets to fill this gap through the design, development, integration and evaluation of technologies for providing a holistic and safe transportation service for children, from their home door to the school door and vice versa. Moreover, one of the results from the pre-pilot indicated the need for education among drivers, parents/children. This need is also on focus within SAFEWAY2SCHOOL through a specific activity. Besides the identification of use cases and the development of software, hardware, HMI and integrated modules, targeted in SAFEWAY2SCHOOL, the largest effort will be spent to test modules, services and training schemes in four different sites in Europe: Sweden, Austria, Italy and Poland. During the verification pilots, the systems will be evaluated regarding their usability, efficiency, user acceptance and market viability; taking into account the very different children’s transportation to/from school systems across the different European regions. Safeway2school is expected to highly contribute to the safety enhancement of the most sensitive and susceptible road users; our children!
REFERENCES
Naturalistic rider studies for the analysis of riders’ behaviour and safety  
“2BESAFE”

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ABSTRACT
Powered Two Wheeler (PTW) users are greatly over-involved in serious and fatal crashes. They have between 5 and 25 times the risk of having a fatal crash compared to car drivers, depending on the country. The number of PTWs on European roads has more than doubled over the last two decades. The recent MAIDS (Motorcycle Accident In-Depth Study) study of PTW crashes in Europe found that behavioural and ergonomic issues were major contributing factors to PTW crashes: the primary accident cause for PTW crashes was the failure of drivers to perceive 2-wheelers and human error was a major contributing factor to most crashes, for both PTW and car drivers [MAIDS, 2008].

The majority of PTW crashes involved a collision with a car. Many large-scale research programs have been undertaken to understand the behavioural and ergonomic factors that contribute to crashes involving 4-wheeled vehicles. These have been effective in informing countermeasure development, which has led to significant reductions in crashes. To our knowledge, no comparable human factors and behavioural research programs have been initiated in the PTW domain, in Europe or elsewhere. The high rate of motorcycle-related deaths and injuries calls for new and refined countermeasures deriving from solid behavioural and ergonomics research.

2BESAFE targets to conduct naturalistic rider studies and analyse the behavioural and ergonomic parameters that contribute to PTW crashes. This includes research on crash causes and human error, the world’s first naturalistic riding study involving instrumented PTWs, research on motorcycle rider risk awareness and perception, the development of new research tools to support the research program, in-depth research on the factors that underlie driver failures to see PTWs and their riders, and the development of recommendations for practical countermeasures for enhancing PTW rider safety. The main expected project impact is the significant reduction of vehicle-to-vehicle collisions involving PTW riders and cars [2BESAFE, 2008].

Within the framework of 2BESAFE will be designed, developed and/or refined research tools for studying riders’ behaviour and performance (instrumented motorbikes, riding simulators), to thoroughly analyse the behavioural and ergonomic issues that contribute to PTW crashes. Studies will be conducted in different European countries, knowledge gained on differences and similarities in the way drivers from different countries interact with PTWs in everyday life will be used to optimise the development of countermeasures in individual countries. Moreover, through the analysis of the results of this multi-level study, the project will develop recommendations for improving PTW design (especially in relation to the Human-Machine Interface and vehicle conspicuity), as well as concise training curricula for riders’ training and licensing, expanded also to training on drivers’ perception for riders.
1 INTRODUCTION

Many large-scale research programs have been undertaken in Europe and abroad to understand the behavioural and ergonomic factors that contribute, alone and in combination, to crashes involving 4-wheeled vehicles. This has involved laboratory research, simulator research, observational studies, naturalistic driving studies, and human error research. From this research, integrated countermeasures have been developed for car drivers to reduce fatalities (for example, through public education, improved training, graduated licensing, automatic speed enforcement, infrastructure measures like better adapted guard rails, ITS technologies, and so on). This work has been effective and the resulting reduction in fatalities, in Europe and elsewhere, has been appreciable. (Although while there are awareness campaigns to educate car drivers in their interaction with PTWs, specific testing and training to look for PTWs is lacking in nearly all European countries).

However, no comparable human factors and behavioural research programs have been initiated in the PTW domain. In part, this is because the psychological and human factors communities have not chosen to focus on PTW safety as an area of research interest. It is also a consequence of a lack of suitable research tools, such as instrumented PTWs and PTW simulators that until now have not been available to properly study motorcycle rider behaviours.

In the past, PTW research has tended to focus on improving the understanding of rider accidentology, road design, rider and driver attitudes to PTW safety, the protection and conspicuity of riders clothing and to a lesser extent, the development of passive and active safety systems.

To our knowledge, the study of the normal (or naturalistic) behaviours of PTW riders in actual and emergency riding situations, which is a prerequisite for the proper understanding of the motives and decision processes that underlie rider performance and safety, has never been studied. Such studies are necessary for the design of relevant and adapted countermeasures.

The disproportionately high rate of motorcycle-related deaths and injuries – stemming primarily from rider and driver error - calls for new countermeasures to be developed, deriving from innovative human factors and ergonomics research, to supplement existing initiatives and programs. The aim of this project is to design and implement a broad-ranging research program that produces fundamental knowledge of PTW rider behaviour, performance, and safety - alone and when interacting with other road users - that can be used to inform and the development of a broad, and integrated, package of countermeasures/public policies for improving the safety of PTW riders in Europe. These countermeasures will include, but will not be limited to the following: data collection and analysis; education, training; vehicle design, including rider protection; road design; legislation and enforcement; licensing; and further research.

2BESAFE outlines an innovative program of research, involving partners from Europe, Israel and Australia, that directly targets those behavioural and ergonomic factors cited in the MAIDS study as contributing to PTW crashes.

2 THE CONCEPT

Powered Two Wheeler (PTW) users are greatly over-involved in serious and fatal crashes. Between 2002 and 2005, PTW deaths as a proportion of the total number of road deaths in European countries increased from 11.3% to 13.4% (CARE, 2008).

The number of PTWs on European roads has more than doubled over the last two decades. The recent MAIDS (Motorcycle Accident In-Depth Study) study of PTW crashes in Europe found that behavioural and ergonomic issues were major contributing factors to PTW
crashes (MAIDS, 2008). The majority of PTW crashes involved a collision with a car. The primary accident cause for PTW crashes was the failure of car drivers to perceive two-wheelers. The behavioural and ergonomic factors contributing to accidents involving four wheeled vehicles have been studied for a long time through laboratory and simulator research, observational studies and more recently naturalistic driving studies, leading to countermeasures to reduce fatalities. There is no comparable research for powered two vehicles, and there is a lack of research tools, for example, motorcycle simulators to study motorcycle rider behaviour.

2BESAFE designs and implements a broad-ranging research program that produces fundamental knowledge on PTW rider behaviour and on interaction between PTW riders and other road users. The produced knowledge will be used to propose relevant countermeasures to mitigate fatalities and injuries (2BESAFE, 2008).

3 PROJECT OBJECTIVES
Within the framework of 2BESAFE will be designed, developed and/or refined research tools for studying riders’ behaviour and performance (instrumented motorbikes, riding simulators), to thoroughly analyse the behavioural and ergonomic issues that contribute to PTW crashes. Studies will be conducted in different European countries, knowledge gained on differences and similarities in the way drivers from different countries interact with PTWs in everyday life will be used to optimise the development of countermeasures in individual countries. Moreover, through the analysis of the results of this multi-level study, the project will develop recommendations for improving PTW design (especially in relation to the Human-Machine Interface and vehicle conspicuity), as well as concise training curricula for riders’ training and licensing, expanded also to training on drivers’ perception for riders.

The innovative program of research targeting on the behavioural and ergonomic factors contributing to motorcycle crashes focuses on the following scientific issues:
- to analyse the crash causes and human error,
- to realise the world’s first naturalistic riding study involving instrumented PTWs,
- to examine PTW riders’ perception and acceptance of risk,
- to develop new research tools to support the research program, in-depth research on the factors that underlie driver failures to see PTWs and their riders,
- to develop recommendations for practical countermeasures for enhancing PTW rider safety.

4 EXPECTED RESULTS
2BE AFE will be the first study designed and implemented at a large-scale, integrated, program of research on the behavioural and ergonomic factors that underlie PTW crashes. The countermeasures proposed will target the most critical safety problems identified in the MAIDS project. The implementation of the countermeasures will have the greatest impact possible in reducing road trauma for PTW riders. Specific recommendations will be made for improving PTW conspicuity, and actual technologies for improving PTW complicity will be developed and tested. The most “innovative technologies” will be six instrumented PTWs for naturalistic riding studies and two riding simulators which be used to study rider behaviour and performance in both normal and emergency riding conditions.

This includes fundamental research on crash causes and human error (WP1), the world’s first naturalistic driving study involving instrumented PTWs (WP2), experimental research on motorcycle rider risk awareness and perception (WP3), the development of research tools to support this human factors and behavioural research program (WP4), a large-scale research
program on the factors that underlie driver failures to see PTWs and their riders (WP5), and the development of practical countermeasures for enhancing PTW rider safety deriving from all these activities (WP6). The relevant implementation steps are shown in the Figure 1 below.

<table>
<thead>
<tr>
<th>WP 1</th>
<th>WP 2</th>
<th>WP 3</th>
<th>WP 4</th>
<th>WP 5</th>
<th>WP 6</th>
<th>WP 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-depth accident analysis</td>
<td>Naturalistic driving</td>
<td>Cross-cultural analysis</td>
<td>Design/tuning of tools</td>
<td>In-depth behavioural studies</td>
<td>Transversal analysis and guidelines</td>
<td>Dissemination/exploitation</td>
</tr>
<tr>
<td>- behavioural based studies</td>
<td>- naturalistic analysis</td>
<td>- conflict studies</td>
<td>- instrumented vh.</td>
<td>- conspicuity</td>
<td>- management</td>
<td></td>
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<tr>
<td>- infrastructure based studies</td>
<td>- driving simulators</td>
<td>- infrastructure</td>
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<td>- weather-based studies</td>
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Figure 1: 2BESAFe implementation steps.

5 NATURALISTIC RIDING STUDIES

Naturalistic driving studies, that have to-date involved the deployment of 4-wheeled vehicles, provide a unique insight into driving behaviour and performance, in normal, near-critical and critical situations. The goal of this WP is design and conduct, for the first time, a naturalistic riding study involving instrumented PTWs. This will allow us to understand, in detail, typical PTW rider behaviour and performances (especially with reference to safety-critical situations) and, based on this understanding, suggest where PTW rider safety countermeasures could best be targeted (for example, focusing on infrastructure, vehicle design or rider training).

Within 2BESAFe, the first step will be to review the design, methods, implementation strategies and outcomes of previous naturalistic driving studies that have been undertaken.

As all past research in this field is related to 4-wheeled vehicles, it will be necessary to transfer the knowledge from naturalistic driving studies of 4-wheeled vehicles to PTWs; and where it is not applicable, to improve and to develop new ideas.

The next step is to develop a detailed methodology for conducting a series of parallel naturalistic riding studies in Europe, involving several instrumented PTWs. The design of the methodology will be largely informed by the outputs of the analysis of previous naturalistic studies. The results of this step will provide the scientific framework for the actual conduct and analysis of the naturalistic riding studies to be undertaken in the final step.

The final step will focus on the design and conduct of the naturalistic riding studies. Riding data will be collected in four countries: the UK (TRL), France (INRETS-MSIS and
CEESAR), Italy (UNIFI and CIDAUT), and Greece (NTUA and UoT). Using a common framework, data will be analysed by the four countries involved; each of the four countries involved in the naturalistic study will be responsible for their own data analyses.

The design of the Naturalistic Riding Study will address the various issues identified in Activity2.1. The following issues, in particular, will be addressed:

1) Definition of riding behaviours and experimental scenario design. This involves definition of the riding behaviours to be observed, parameters to be recorded to enable these behaviours to be measured, choice of participants (number, experience, age, gender, demographic characteristics, etc), and the specific elements of the road environment (for example urban/interurban, daytime/night-time etc) for which data must be sampled.

2) Tools to be used. This involves the specification of product and acceptance testing procedures, equipment installation and de-installation procedures, technical support and maintenance strategies.

3) Data issues. Data collection (objective and subjective) and analysis tools, and procedures for collecting, downloading, reducing, filtering, storing and analysing data, analysis methods will be specified.

4) Conduct of experiment. All relevant aspects will be considered - ethical, legal and logistic implementation issues, experimental design, subject recruitment, briefing, training and exit procedures.

5) Implementation strategies to support a successful study. The physical steps and actions necessary in realising the experimental design will be determined. This will be largely informed by the outputs of the previous studies analysis.

The work will be conducted in two phases. The first will involve the preparation of an experimental design report which will present and discuss all critical issues. The second phase involves the design of a draft implementation plan which will define the practical tests and steps involved in realising the naturalistic riding study design.

6 TOOLS FOR CONDUCTING NATURALISTIC STUDIES

One of the primary objectives of 2BESA is to develop tools that will support research for conducting naturalistic on rider and driver behaviour. Specifically it is planned to:

- instrumenting six Powered Two Wheelers, thus enabling these vehicles to be used to collect and record data on riding behaviour and performance;
- instrumenting one research car, thus providing the possibility to collect and record data on driver behaviour and performance when interacting with PTW riders;
- improving the rendering of two existing PTW simulators, focusing in particular on rider feel, thus enabling the vehicles to be used in a validation study;
- improving the visual rendering of an existing research car driving simulator (calibration of the rendering, improvement in the rear view mirror rendering), and the design of software for simplifying the off-line analysis of drivers’ visual activity; and
- designing a set of shared tools (video films) for studying rider cognition and behavior (especially risk perception and assessment) that also enable cross-cultural and sociological comparisons in Europe.
7 CONCLUSIONS
Powered Two Wheeler (PTW) users are greatly over-involved in serious and fatal crashes. Between 2002 and 2005, PTW deaths as a proportion of the total number of road deaths in European countries increased from 11.3% to 13.4%.

To-date, the study of the normal (or naturalistic) behaviours of PTW riders in normal and emergency riding situations, which is a prerequisite for the proper understanding of sensory, perceptual, decision and attentional processes that underlie rider performance and safety, has never been studied. In-depth interactions between riders and drivers have also never been studied, and nor has there been previous research undertaken specifically to classify the full range of errors, operator and latent (i.e., organisational) that underlie PTW crashes. Such studies are, however, necessary for the design and development of new and adapted countermeasures. From these stand-points, the 2-BE-SAFE project is unique, and very innovative.

2 BE SAFE will be the first study designed and implemented at a large-scale, integrated, program of research on the behavioural and ergonomic factors that underlie PTW crashes.

2BESAFE designs and implements a broad-ranging research program that produces fundamental knowledge on PTW rider behaviour and on interaction between PTW riders and other road users. The produced knowledge will be used to propose relevant countermeasures to mitigate fatalities and injuries.

8 REFERENCES


ABSTRACT

The number of road fatalities in Member States is decreasing too slowly to meet the EU-targets. A new generation of measures is needed, underpinned by a new generation of research methods. Recent technology developments allow for this: naturalistic observations or naturalistic driving. The recently started European project PROLOGUE aims to prove the feasibility and usefulness of a large-scale European naturalistic driving study. In the typical naturalistic driving study, traffic situations and drivers are studied unobtrusively by using small cameras and other equipment, placed in drivers’ own cars, during day-to-day trips, and without the presence of a test supervisor. Results will lead to a better understanding of the factors that affect road safety and the ways to improve it.

PROLOGUE consists of various activities, including the identification of relevant application areas and research questions, the identification of currently available technology for collecting, storing and analysing data, and an inventory of methodological, organisational and legal issues. In five different small-scale field studies several issues are piloted in practice. Substantial effort is put into communication and dissemination in order to gain the support for and involvement in a large-scale European study of a wide variety of stakeholders, including car industry, insurance companies, driver training and certification organisations, road authorities, and governments. Whereas road safety is the main motive, the project will also look at the relevance for environmental issues, e.g. CO2 emissions, and traffic management.

PROLOGUE is part of the seventh Framework Programme of the European Commission and started on 1 August 2009. The project will run for two years. The consortium consists of nine partner institutes, co-ordinated by SWOV Institute for Road Safety.

1 INTRODUCTION

Road crashes are a major problem of any society in the world. In 2001, in its White Paper the European Commission (EC, 2001) stated that about one in three persons will be injured in a road crash at some point of their lives. At that time, in the 15 EU countries almost 40,000 people were killed in traffic and the total costs were estimated at 2% of the GNP of the European Union, equalling 160 billion Euro. The European Commission therefore targeted at
a 50% reduction of the number of road deaths by 2010. This was a very ambitious target. Now, 8 years later, and including 12 new Member States, it is indeed unlikely that the EU-target will be met. According to a survey of the European Transport Safety Council ETSC (Jost et al., 2009) only Luxembourg, France, Portugal, Spain and Belgium are on course to achieve the target. These countries achieved reductions ranging from 43% to 49% between 2001 and 2008. However, in that period, the average reduction in the 27 EU countries was, with 28%, much lower.

These figures show that a major breakthrough in effective policies and measures is needed to realise further road safety improvements. The basis of any effective road safety policy and road safety measure is research, providing insight in how and why crashes evolve and thus enabling effective engineering, enforcement or educational measures. Traditionally, the road user, the vehicle and the infrastructure were considered to be rather independent elements of the road transport system. This view has led to some very effective measures such as police enforcement on drink-driving, the implementation of roundabouts, and mandatory seat belt use. In most countries these measures have been implemented successfully. For further improvements, however, a new generation of road safety measures is needed, based on the recognition that the road, the road user and the vehicle are not independent but indeed part of an integrated road transport system, that also includes the interaction with other road users and specific external circumstances. To identify new effective measures, we need new research methods. Important developments in technologies, in particular in information and communication technologies (ICT), have now created many opportunities for this.

2 THE NATURALISTIC OBSERVATION APPROACH

These new technologies can help to realise a breakthrough in road safety research, namely by means of the naturalistic observation approach. In a naturalistic observation approach, the behaviour of road users is observed unobtrusively in a natural setting for a long period of time. Technological improvements in data collection, data storage capacities, data-mining, image processing, webcams, et cetera, have made it possible to observe road users unobtrusively, and collect and analyse huge amounts of data.

A specific application of naturalistic observations is naturalistic driving. Typically, in a naturalistic driving study passenger cars, generally the subjects' own cars, are equipped with devices that continuously monitor various aspects of driving behaviour, including information about vehicle movements -e.g. acceleration, deceleration, position on the road, driving speed-, about the driver -e.g. eye, head and hand movements-, and about the direct environment -e.g. traffic densities, time headway, road and weather conditions. This technique makes it possible to observe and analyse the interrelationship between driver, vehicle, road and other traffic in normal situations, in conflict situations and in actual crashes (see Figure 1 for an example of video images). Similarly, motorcycles could be equipped for naturalistic observation purposes: naturalistic riding. Since it is more difficult to equip cyclists and pedestrians, naturalistic site-based observations units are a useful addition for increasing our knowledge about the specific problems of these vulnerable road user groups.

Compared to the naturalistic observation approach, the more traditional research tools, like driving simulators, instrumented cars and (micro)simulation models have some major drawbacks. With these traditional tools it is for example, hardly possible to observe the ultimate object of interest, i.e. crashes or near crashes. Analysing police registration and safety performance indicators may have an important general monitoring function and form a basis for detecting specific safety problems. However, they are of very limited use for explaining how and why a crash occurred as well as for defining remedial measures and evaluating their effects. This is especially true for the assessment and evaluation of all kind of new technologies (both in-car and road-side). Whereas, in-depth crash analysis is a valuable
additional instrument to reconstruct a crash, it is unable to determine what exactly happened before the crash, for example, what the driver was doing. Besides, the in-depth analysis method implies that it can only become operational once a crash has happened and it could be considered rather unethical to wait for crashes before action is taken.

Systematic observations of road user behaviour in their natural environment, combined with knowledge of human information processing capabilities and limitations, offer much wider perspectives in understanding the causes of safety problems and modelling driver behaviour in both normal and critical situations. And that is the role a naturalistic observation approach can play. For well known risk factors such as distraction and fatigue, naturalistic observations are actually the only method that would provide reliable information about their prevalence and the actual relationship with crashes. Other issues for which naturalistic observations would be an ideal method include:

- The effect of road design characteristics, or weather conditions on the interaction between driver and vehicle;
- Comparing the driving style of specific road user groups, e.g. novice drivers, elderly;
- The prevalence of mobile phone or other in-car information devices and the relationship with particular behaviour patterns or crashes;
- The effect of passengers on distraction, particular driving behaviour or incidents/crashes;
- The interaction between motorised vehicles and vulnerable road users;
- And many other ...

One of the additional advantages of naturalistic studies is that during the data collection phase a huge data base is built up. This same data base can be used for different purposes. It could be used to answer different research questions by simply reanalysing the data, without requiring additional data collection. The database could also be used as the before measurements of a before-after research design and as such allowing for the evaluation of particular interventions. In short, naturalistic studies offer a high research potential.

Figure 1: Example of the inside and outside video image in the US trials (Source: LLC, 2008)
3 SOME OTHER NATURALISTIC OBSERVATIONS INITIATIVES

The potential of naturalistic observations is proven in the United States in what got known as the '100 cars study' (e.g., Dingus et al., 2006; Klauer et al., 2006). In this study 100 fully equipped cars were driven in Washington DC and the Northern Virginia area for one year. In the end the dataset included around 2 million vehicle miles, 43 thousand hours of data, 241 drivers. The data included 15 police-reported crashes, 67 non-reported crashes, 761 near-crashes and 8,295 incidents. The data were used for several analyses focusing on different research questions. One of the interesting outcomes was the prominent role of distraction in crashes, near crashes and incidents.

The success has led the United States to start a large-scale project in the Strategic Highway Research Project 2 (SHRP2) on naturalistic driving, involving at least 2,500 instrumented vehicles to be operated over a period of 2 to 3 years. Volunteer drivers will drive their own vehicles for their own everyday use. The data collection will focus on lane departure and intersection crashes, but also allow for studying many other research questions (see: http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Public/Blank2.aspx).

In the US and Australia, but also in Europe, the naturalistic driving approach becomes increasingly popular as a means to evaluate new in-car technologies in what is known as Field Operational Tests (FOTs). So far, these are rather small-scale studies performed by joined governmental, research and car industry partnerships. In Europe, the FESTA project (see: http://www.its.leeds.ac.uk/festa/) worked on the development of a best practice handbook to test the impact of ICT-based systems by means of scientifically robust and efficient FOTs. EuroFOT (see: http://www.eurofot.org/) and TELEFOT (see: http://www.telefot.eu/) are two recent larger-scale initiatives to implement the FESTA recommendations.

Naturalistic driving is also used as a tool in three other European projects. These are INTERACTION, a project that focuses on the interaction between driver and in-vehicle technologies (see: http://interaction-fp7.eu/), and 2BSAFE, a project that focuses on the safety of motorised two-wheelers (see: http://www.2besafe.eu). January 2010 the DaCoTA project is planned to start. One of its working packages (WP6) looks at the possibilities of naturalistic observations as a specific tool for monitoring safety performance indicators, near crashes and detailed exposure data as input to the European Road Safety Observatory ERSO.

As indicated, there are various other initiatives, both in- en outside Europe, that use naturalistic observations as a tool, mainly to get an answer to a specific question. PROLOGUE comes in from a broader perspective, because, as an equivalent of the US SHRP2 project, it aims to pave the road for a large-scale European naturalistic study. Such a large-scale study would allow for collecting and analysing a wide variety of data that would help to improve the insight in the relationship between road, road environment, road user and vehicle on the one hand and road crashes at the other and in turn would help to develop effective measures.

4 THE PROLOGUE PROJECT

The work in PROLOGUE is divided into six work packages. Figure 2 is a graphical presentation of these work packages and their interrelationship.
4.1 The field trials

The central and largest work package of the project is WP3, the field trials. In order to demonstrate the potential usefulness of naturalistic observations five small-scale field trials will be carried out. These trials also intend to serve as pilot studies for a future large-scale naturalistic study by revealing strengths and weaknesses of the data collected by the various instruments considered, by identifying relevant issues related to implementation and management, by evaluating the collected data in association with safety measures, and by identifying potential problems and gaps in the collected data and the various data reduction and data analysis methods. The results and insights gained from the field trials serve to define recommendations related to methodology, technology, implementation, data management and transferability, as well as to provide a clearer understanding, based on hands-on experience, of the potential usefulness of these data to the study of various research questions.

In order to meet these objectives, the four main research issues addressed by the field trials are:

- Reliability and ease of implementation of the data collection equipment, e.g. related to requirements as continuous data collection, correct identification of the driver, the vehicle location, the driving speed, etc.
- Data reduction and interpretation. The large amount of data collected by naturalistic observations needs to be reduced to meaningful observations of behaviour, i.e. various events that occur. An important question related to this is how relevant the processed indicators are to safety or in other words how accurately they can be used as proxies or surrogate indicators to the risk of crash involvement.
- Relation to self-reports. In many cases, the substitute to naturalistic data is self-reported data. Clearly, the costs associated with these two approaches are strikingly different. Thus, it is important to know what the relation is between the measurements of driving behaviour derived by naturalistic studies and the measures
derived from self-reports. An additional question is how the two approaches can be used in a complementary way.

- Cross country comparability. Theoretically, naturalistic observations are a universal means to assess the behaviour and interaction of road users. However, it is useful to test this assumption by assessing the potential impact of differences in driving culture, infrastructure standards, geographic and weather characteristics et cetera on the various data items collected and on their relations to traffic safety.

- Evaluation of interventions. Naturalistic data are useful not only to provide better understanding of behaviour, but also in evaluating various interventions in a direct way. Therefore, some of the field trials include two phases: in the first phase naturalistic data will be collected without any intervention; in the second phase with an intervention. In the second phase the naturalistic data record the reaction to the intervention and thus enable evaluation of its effects.

The field trials address different relevant road safety issues, including vulnerable road users, young, inexperienced drivers and the use and effect of in-vehicle technology.

4.2 Preceding and following the field trials
WP1 and WP2 precede the field trials. WP1 aims at identifying the potential application areas and research questions for which the naturalistic approach would have added values, based on the experiences so far. It will use literature, existing international networks, and the input from potential users of the knowledge (see Paragraph 4.3). In a similar way, WP2 focuses on the currently available technology for data collection, data storage and data analysis and on the methodological and organisational requirements for naturalistic observations in different types of naturalistic studies. The results of WP1 and WP2 feed into the field trial work package (WP3) so that the final trial specifications can be attuned.

WP4 follows the field trials and aims to set out the principles and recommendations for a future large-scale field trial. To do so, it makes use of the results of the theoretical work in WP1 and WP2 and of the practical experiences in the field trials of WP3. In addition to the recommendations for a future large-scale study, WP4 will also produce the final technical report, providing a concise and accessible overview of the main findings of the project.

4.3 Creating stakeholder involvement
During the project substantial effort is put in communication and dissemination in WP5. Road safety researchers are expected to be very well aware of the huge potential of naturalistic observations for gaining understanding of the factors influencing road safety. However, naturalistic observations are likely to result in very useful information for a wide variety of other purposes and stakeholders as well. For example, insurance companies may benefit because they will get a better insight in risk factors; driver training and licensing organisations may use the knowledge to better tailor their curriculum to the driving characteristics of beginners; and road traffic managers may benefit by using the information to increase the road capacities through improved (dynamic) traffic management. It is important to involve these other potential stakeholders at an early stage, explain the concept of naturalistic observations and, together with them, define the areas of application of the results in their respective branches. WP5 is meant to identify the potential stakeholders, get them interested and involved in the project, the current trials, and disseminate the results in a way to make them understand its added value and the full potential of a large-scale trial for their own purposes. One of the first activities here is the establishment of a User Forum, which will consist of a wide variety of stakeholders including road administrations, car industry, insurance companies, road transport operators, road user organisations, driver training and
certification organisations, as well as knowledge and research organisations. The User Forum will be used both to bring knowledge and information to the stakeholders and to get knowledge and information from them. An up-to-date website with several forums, bi-annual newsletters, two Pan-European workshops and five regional workshops are among the instruments that will be used to realise the information exchange between the potential users.

4.4 Organisational details and time frame
PROLOGUE is being carried out by a consortium of nine partner institutes. The co-ordinator is SWOV Institute for Road Safety Research in the Netherlands. The other partners are CERTH-HIT (Greece), KfV (Austria), Loughborough University (UK), Or Yarok (Israel), TNO (Netherlands), TØI (Norway), Test and Training International (Austria) and the Universitat de València (Spain). In addition, there is an independent, external Advisory Board. The Advisory Board consists of eight renowned experts in the field of road safety in general and of research methods in particular. The Board will advise on the overall scientific approach of the project and the elaboration of the work in each of the work packages.

PROLOGUE is part of the EU Seventh Framework Programme, theme 7, Transport. The work started in August 2009 and will continue until August 2011. The results of WP1 and WP2 will be published in a series of reports that are planned for submission to the EC by the end of January 2010. The results of the individual field trials will be submitted in November 2010; the integrated field trial report in January 2011. The recommendations for a large scale naturalistic study and the final project report are due in June and July 2011. The Deliverables will be made available at the project website (www.prologue-eu.eu) as soon as possible after EC approval.

REFERENCES


WEBSITES:
http://www.trb.org/StrategicHighwayResearchProgram2SHRP2/Public/Blank2.aspx
(last visited: 16 November 2009)
http://www.its.leeds.ac.uk/festa/ (last visited: 16 November 2009)
http://www.eurofot.org/ (last visited: 16 November 2009)
http://www.telefot.eu/ (last visited: 16 November 2009)
http://interaction-fp7.eu/ (last visited: 16 November 2009)
http://www.2besafe.eu/ (last visited: 16 November 2009)
SAFERIDER: CAN BASED ARCHITECTURE ON 2-WHEELERS DOMAIN

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ABSTRACT

This paper will present a new concept of CAN-based (Controller Area Network) architecture developed within the SAFERIDER 7 FP (Framework Program) project. The project aims to improve the comfort and safety of riders in the 2-wheelers domain introducing new functionalities on board. These functionalities are classified as OBIS (On-Board Information System) and ARAS (Advanced Riding Assistance System) and are supported by a multi-points high speed CAN installed in the vehicle. In details, the OBIS developed in SAFERIDER collects 4 functionalities, namely eCall, Telediagnostic System, Navigation and Route Guidance System, Weather Traffic and Black Spot Warning. Respectively, ARAS collects 4 functionalities, namely Speed Alert Functionality (SAF), Frontal Collision Warning (FCW), Curve Warning (CW), Intersection Support (IS) and Lane Change Support (LCS). The aim of the architecture is to set from the very beginning a common framework for ARAS and OBIS functionalities integration in terms of sensors, actuators, positioning on the PTW and HMI (Human Machine Interface) elements and strategies.

On logical side, the CAN-based architecture of SAFERIDER is created on the basis of the three-layer Information Processing Approach developed in PReVENT (6 FP, www.prevent-ip.org), that comprehends the following layers: Perception-Decision-Action. Based on this approach, overall information flow are described from input generated by the sensors to the feedback delivered to the rider. Basically, an architecture developed for a rider assistance system, consists of three parts: the perception level, which is the responsible for the environment and PTW dynamic status perception, the decision and the action level, which are responsible for taking and executing actions.

On HW (HardWare) side, several modules are integrated within a unique multi-nodes CAN bus, covering the functionalities described before. The communications among them follows a common CAN database developed so far during the project in which are collected all the information details exchanged among modules.

Between the several innovation of the SAFERIDER, one of the most important is the fact that it is the first project that considers the introduction of ARAS and OBIS functionalities, based on the integration of several module on PTWs via a CAN network connection.
1 SAFERIDER CONCEPT AND SYSTEM ARCHITECTURE

SAFERIDER is a 3-year research project, launched at the beginning of January 2008 and funded by the EC in the 7th Framework program. The project focuses on the developing of effective OBIS (On-Board Information Systems) and ARAS (Advanced Riding Assistant Systems) and on their integration in a real PTWs’ network. Functions and devices are developed in order to improve riders’ safety and comfort: system data are elaborated in useful information, that are delivered to the rider through an effective HMI, that is the fulcrum of the communication with the rider. The SAFERIDER system is based on modular, inclusive and standards-abiding system architecture, that allows connections between different sensors and multiple hardware. The starting concept of PTW architecture is displayed in the following figure:

Figure 1: Starting Block Diagram of SAFERIDER

The architecture aims at setting a standard and modular framework in which different ARAS and OBIS modules could exchange data and communicate among them. The most promising architecture solution, in terms of efficiency, elaboration times, flexibility and robustness on real motorcycle network arises from the results of several studies aimed at investigate the best way to deliver signals. The functionalities taken into consideration (Figure 1) within SAFERIDER are:

- OBIS: eCall, Telediagnostic System, Navigation & Route Guidance, Traffic, Weather & Black Spot Warning
- ARAS: Frontal Collision Warning, Curve Warning, Speed Alert Functionality, Intersection Support and Lane Change Support;

About OBIS, relevant applications come out in the last decade, especially in the automotive domain, both as aftermarket devices and as standard vehicle equipment. As a consequence, PTW manufacturers developed a high interest in the implementation of such technologies in their vehicles.

Both for the automotive domain and the PTW domain, one of the most interesting application is surely Navigation and Route Guidance (N&RG). It is a matter of fact that the concerning navigation devices for PTW must be tailored for the rider, redesigning the existing devices, that don’t cope with riders’ needs and with their widely different context.
For these reasons, within SAFERIDER Navigation and Route Guidance play a key role. Moreover they have been integrated with traffic and weather information in order to notify the rider the potential risks he may encounter during the trip. Traffic and weather data are downloaded in real time from a server via GSM and are related to the area in which the PTW is located. Moreover, Navigation and Route Guidance provides also black spot information, that means warnings about locations in which PTWs are significantly involved in accidents. The black spot database is stored on the memory device and could be updated whenever the rider wants.

If the PTW is crashed or is fallen, the eCall functionality starts automatically, sending via GSM information about the location of the crash/fall to the emergency center. Afterwards, the center will call both PTW phone number (SIM card in eCall submodule) and mobile phone in order to reach the rider and to check his/her real conditions, taking then the appropriate countermeasures.

Finally, telediagnostic services represent another added value for the final customer, because it constantly monitors the most critical operational parameters of the PTW (e.g: brake usage and conditions, oil and temperatures, PTW usage, etc). The functionality provides a web tools in order to have the possibility to check PTW status in a easy and comfortable way, informing on potential needed services or failures of a vehicle subsystem.

On the other side, in comparison to ADAS (four-wheels domain), ARAS (two-wheelers domain) must take into account the limitations of the vehicle dynamics. In fact the User Centred Design Methodology and scientific literature about usability and automated systems elicit all the huge amount of drawbacks due to an active intervention on the vehicle, that in the most part of cases can cause maneuverability problems or risk accident to the rider. The side effect of automatic intervention are well documented in the literature about the Out-Of-The-Loop performance and the cost of automation. As a consequence, the ARAS role can only be that of a proactive and intelligent warning provider which is able of considering key accident parameters such as speed, difficulty to approach a curve, obstacle collision and, in general, intersection scenarios.

A second important ARAS realization is the Speed Alert Functionality, that could help the rider, especially novice riders or high power motorcycles riders, to keep under control the PTW speed in that roadway section. If there will be an overspeeding (a certain percentage above the legal speed), the system will warn the rider which will be able of reducing the speed, avoiding a periodically monitoring of it.

AN undoubtedly key contributor to motorcycles accidents is the wrong curve approach. In order to give a support to this demanding task SAFERIDER proposes , a Curve Warning functionality that elaborates the principal dynamic characteristics of the PTW approaching maneuver, taking into consideration dynamic data as roll, pitch, yaw rate, speed, acceleration and the geometry of the curve.
During approaching phases, the function processes in real time the actual maneuver, correlating it to the reference maneuver and then calculating the differences. In this way the application is aware of the kind of correction that the rider should perform in order to safely facing the curve.

Unfortunately, among the PTW accident causes, the frontal collision is unquestionably the trigger of more than 50% of the total accidents. The Frontal Collision Warning detects potential obstacles scanning the frontal area through a LASERScanner. The LASERScanner is a sensor that detects the type of obstacles, and then calculates its position and dynamic characteristics. Based on the PTW dynamics data, there is a function that infer whether there will be an imminent potential collision risk. If it is the HMI module sends a warning to the rider. In this way, the rider could undertake the required counter maneuver to prevent the potential collision.

Merging the 3 abovementioned applications comes out the most challenging function: the Intersection Support. Since it is expected to be the most complex function, it will be tested in simulated environment.

Again, also for ARAS functions, these applications have significantly increased in the last years. Since the automotive OEM (Original Equipment Manufacturer) are close to the industrialization of such functions in cars, the 2-wheelers OEM are really interested in these functionalities which don’t exist in the global market yet.

2 SAFTERIDER LOGIC
According to PReVENT strategy a logical architecture has been developed in order to cover all the initial functionalities planned in the project (see Figure 3).

![Figure 3: System Architecture Proposal based on PReVENT Strategy](image)
2.1 Input
Starting on the left side, the *INPUT* column contains all the physical and virtual sensors that provide the information on the basis of PTW dynamics, environmental characteristics and infrastructure. The inputs come from the following sensors:
- **LASERScanner**: to provide a model of the frontal environment with contemporaneous obstacles in the frontal area.
- **Gyrometers**: to measure PTW roll, pitch, and yaw rate, according to the system coordinate.
- **Accelerometers** (Acc-meters): to measure longitudinal (x), lateral (y) and vertical (z) accelerations, according to the system coordinate.
- **Others Sensors**: to provide information to Telediagnostic System.
- **Helmet Fasten**: to provide information about helmet fastened/not fastened.
- **N&RG touchscreen**: to provide inputs from riders.
- **Weather, Traffic, Speed Limit, Maps and Black Spot**: currently considered as virtual sensors to provide relevant information;
- **GSM/GPRS/UMTS**: to provide to PTW information regarding traffic and weather in real time from infrastructure.
- **GPS (Global Positioning System)/GALILEO**: to provide PTW position and speed.
- **Rear sensor**: to provide a model of the rear environment with contemporaneous obstacles in the rear area.

2.2 Perception
The *PERCEPTION* layer aims at collecting relevant data from several sensors the vehicle is equipped with (e.g.: outcome from sensors as LASERScanner or inertial platform) and from the infrastructure via a dedicated GSM communication with the vehicle.

The inputs from sensors are provided by both physical and virtual connections to the relevant part in the perception layer, which are structured in accordance with Figure 3, and quantified as follows:

- **PTW status**:
  - **Diagnostic**: diagnostic, logistics, performance and anti-theft security provided by other sensors (e.g: helmet fasten, brake statistics, oil level, modules failure, etc).
  - **Position**: PTW position provided by GPS or GALILEO.
  - **Speed**: PTW absolute speed provided by GPS or GALILEO.
  - **Acceleration**: longitudinal, lateral and vertical ones (accordingly with SAE definition, respectively x,y,z) provided by accelerometers.
  - **Angle**: roll, pitch and yaw angle (then inputs elaboration provided by gyrometers).

- **Environment**:
  - **Frontal Area**: information about frontal area regarding obstacles provided by LASERScanner and image processing.
  - **Maps**: navigation-related information, road characteristics, legal speed, etc.
  - **Traffic**: information about traffic provided in real time by infrastructure.
  - **Weather**: information about weather provided in real time by infrastructure.
  - **Black Spot**: information about dangerous point stored within maps.
  - **Rear Area**: information about rear area regarding obstacles provided by Rear Sensor and image processing.

At the Perception Layer, the data are merged by PROFUSION theory (PReVENT subproject).
2.3 Decision

Afterwards, data are elaborated via software and sent to the *DECISION* layer that analyses and predicts potential safety critical driving conditions, enables communications with infrastructure, manages the navigation and telematic information.

The Decision layer is separated into ARAS and OBIS functionality (as project suggested):

- **ARAS**:
  - Frontal Collision Warning.
  - Curve Warning.
  - Speed Alert Functionality.
  - Intersection Support (only on simulator).
  - Lane Change Support.

- **OBIS**:
  - eCall.
  - Telediagnostic System.
  - Navigation & Route Guidance.

The connections between Perception and Decision layers are designed according to related sub-systems requests (in the Figure 3 colours are just used as separators):

- **Frontal Collision Warnings** requests data regarding:
  - Position: to understand where the PTW is.
  - Speed: to understand the dynamic characteristics.
  - Acceleration: to understand the dynamic characteristics.
  - Roll, pitch, yaw angles: to take into consideration the LASERScanner beam inclination created by the PTW actual angles.
  - Frontal area: to localize obstacles and their dynamics (e.g. their associated speeds etc).
  - Maps: to provide information regarding the road geometry in order to understand the real risk of dangers.

- **Speed Alert** requests data regarding:
  - Position: to understand in which area the PTW is located.
  - Speed: to understand the dynamic characteristics of the PTW.
  - Speed limit (maps): to compare the PTW actual speed against designated legal speed limit assigned to road.

- **Curve Warning** requests data regarding:
  - Position: to understand where the PTW is.
  - Speed: to understand the dynamic characteristics.
  - Acceleration: to understand the dynamic characteristics.
  - Roll, pitch, yaw angles: to understand the dynamic characteristics.
  - Maps: to understand the curve distances and geometry (based upon point to point interpolation).
  - Frontal Area: to understand oncoming scenario.

- **Intersection Support** (3 last ARAS integration) requests data regarding:
  - Position: to understand where the PTW is.
  - Speed: to understand the dynamic characteristics.
  - Acceleration: to understand the dynamic characteristics.
– Roll, pitch, yaw angles: to understand the dynamic characteristics.
– Maps: to understand the curve distances and geometry (based upon point to point interpolation) and the speed limit.
– Frontal Area: to understand oncoming situation.

• Lane Change Support requests data regarding:
  – Position: to understand where the PTW is.
  – Speed: to understand the dynamic characteristics.
  – Roll, pitch, angles: to take into consideration and estimate the current and the next manoeuvres.
  – Rear area: to localize obstacles and their dynamics (e.g. their associated speeds etc).
  – Maps: to provide information regarding the road geometry

• eCall requests:
  – Position: to understand where the PTW is (in this case, the data is transmitted by the MetaSystem proprietary protocol).
  – Speed: to detect a crash or fall and identify whether crash or fall (jointly with accelerometers data).
  – Acceleration: to detect crash or fall and identify whether crash or fall (jointly with speed data).
  – Maps: to transmit the PTW directions and position characteristics.
  – Roll, pitch, yaw angles: to understand the crash or fall.

• Navigation & Route Guidance:
  – Maps: to provide the rider with correct information regarding route selected.
  – Speed: to understand the dynamic characteristics.
  – Position: to understand where the PTW is.

• Traffic requests:
  – Position: to understand where the PTW is.
  – Maps: to identify the selected route.
  – Traffic: to understand the traffic situation (based upon TMC, FM radio, etc received from infrastructure).

• Weather requests:
  – Position: to understand where the PTW is
  – Maps: to identify the route
  – Weather: to understand the weather situation (based upon data received from the infrastructure).

• Black Spot requests:
  – Position: to understand where the PTW is.
  – Maps: to identify possibly black spot along the route.
  – Black Spot: to provide information about dangerous point.

Basically, the separation between sub-modules gathered within Decision layer concerns only thelogical side: for example the N&RG covers a key role and some sub-modules are integrated within the same hardware. For the same reasons, some ARAS can be integrated in the same HW. Once the decision is taken, this layer accomplishes mainly two tasks: , elaborating the inputs, and providing the relevant information to the HMI ACTION layer.
Within HMI Action layer, actions to be taken are elaborated: this is in fact responsible of managing the outputs of the system to the rider.

2.4 HMI Action

Whether an information could be delivered or not is a decision based on the priority of the information as well as the PTW status. The architecture (in terms of laws and rules) of the priority manager has been developed and investigated in order to manage possible conflicts between various warnings and situations, that have been studied in order to avoid active intervention on vehicle dynamic motion and controls, as motorcycles are more unstable than a 4-wheels vehicles. Basically, several HMI components have been designed in order to transmit safely and immediately the message contents. The layer named HMI ACTION is basically a priority manager: it decides which information deliver to the rider and if deliver it in case of contemporary warnings or multi-warnings available at the same time. The choice criteria are the information importance for the rider as well PTW situation, status, etc. The developing of such priority laws explores to the solutions to manage possible conflicts between various warnings and situation. Alternatively, different HMI channels can be envisaged and maybe used.

2.5 Output

The last layer, named OUTPUT layer, gathers the HMI devices utilized to provide relevant information-warnings both to the rider and to the infrastructure:
- N&RG display: video feedback placed in the dashboard.
- Head Up Display: video feedback placed in the helmet.
- In-helmet Speakers: audio feedback placed in the helmet.
- Haptic Handle: haptic feedback placed in the throttle.
- Haptic Throttle: haptic feedback placed in the throttle.
- Haptic Seat: haptic feedback placed in the seat.
- Haptic Bracelet/Glove: wearable haptic feedback.
- Adaptive Light: to correctly illuminate the frontal area during riding.

3 CAN HISTORY AND APPLICATIONS

The CAN serial communications was originally developed for real-time control applications in the early 1980s within automotive domain. The CAN protocol began an international standard in 1993 defined in the ISO11898-1 and ISO 11519 for lower-speed applications. High-speed CAN reaches 1Mbps and is used for engine control and powertrain applications. Low-speed/fault-tolerant CAN reaches 125Kbps and is used for body and comfort devices.

Now it is widely supported by the semiconductor manufacturers in the design of in-vehicle networks for a wide range of cars, millions of which have been manufactured during the last decade.

For these reasons, the CAN bus is a sort of ‘standardized’ bus for this type of applications, offering a wide range of advantages:
- Lower wiring complexity. This factor plays an especially large role in automotive and motorcycle sectors.
- Availability of several low-cost CAN controllers and interface devices as off-the-shelf components.
- An economical and easy to manage twisted wire pair serves as the transmission medium.
- Custom built devices and popular microcontrollers with embedded CAN controllers are also available.
- CAN stations can be subsequently added to and removed from the existing CAN bus relatively easily. Only the connection to the bus line must be made or disconnected. This aspect plays a significant role, especially with trouble shooting and repairs.
- Availability of CAN-related system development packages, hardware interface cards and easy-to-use software packages that provide system designers, builders and maintainers with a wide range of design, monitoring, analysis, and test tools.
- The breakdown of a CAN station has no immediate impact on the CAN bus. All the other stations can communicate unconstrained. In fact, if one network node is defect the network is still able to operate.
- A sender of information transmits to all devices on the bus, so all receiving devices read the message and then decide if it is relevant to them. This guarantees data integrity as all devices in the system use the same information. There are also sophisticated error detecting mechanisms and retransmission of faulty messages, which guarantees data integrity.

4 SAFERIDER HW
On HW side, the CAN network has 8 nodes: LASERScnner Unit, ARAS Control Module, Lane Change Radar, Lane Change ECU, Navigation Unit, Telematic and security Service Unit, Vehicle Interface and HMI Manager.

![Diagram of CAN network](image)

**Figure 4: on board CAN network**

For the communication exchanging, a dedicated DBC (DataBaseCAN) has been developed in order to set a common base for the various demonstrator expected by the project. In details, SAFERIDER network uses a standard identifier (11 bit) and a high-speed (500kbs), both Motorola and Intel order.
3.1 ARAS Modules

Basically ARAS components are placed on the left side of the Figure 2 in orange color. LASERScanner scans the frontal area in order to elaborate and create a virtual scenario with objects and relevant characteristics. Regarding dynamics data, as angles rate (yaw, roll and pitch), GPS, speed and accelerations, LASERScanner is connected via RS232 (Recommended Standard 232) to an IMU (Inertial Machine Unit), that is specifically an inertial platform. The IMU contains accelerometers, gyroscopes, 3D magnetometers, an integrated GPS receiver, a static pressure sensor and temperature sensor.

ARAS Control Module is responsible of all ARAS functionalities, except for the LCS one, that elaborates the information provided via CAN regarding object, dynamics and maps data, and providing the relevant warning to the CAN bus.

The LCS unit is the responsible of the rear area detection and of the algorithm tracking while the LCS ECU elaborates data object and contains the warning strategies.

3.2 OBIS Modules

On OBIS side (green blocks in the Figure 2), Telematic and security Service Unit bridges the SAFERIDER system and the infrastructure (server), exchanging information regarding emergency call (eCall), diagnostic information, weather and traffic situation.

Diagnostic information concerns the maintenance and the use of the vehicle (e.g.: brake usage, oil levels and temperature, etc). These data are provided from other vehicle networks to CAN via VIF, (Vehicle Interface). Moreover, every module publishes on the CAN bus a failure messages in order to keep the network always fully well-functioning and the rider aware about potential failure of the sub-system.

Through the CAN line, Navigation and Route Guidance Unit receives various messages and displays not only navigation and black spot signals, but also info/warnings messages generated by other modules (e.g. from Telematic and security Service Unit, ARAS Control Module) under the control and coordination of the HMI Manager.

3.3 HMI Elements

As mentioned, HMI Manager handles the CAN bus especially about the HMI aspect: it provides to various HMI devices relevant inputs, following priority laws stored in its memory. The HMI devices are connected by CAN, BlueTooth, serial RS232 and digital links.

Since a lot of information that may be useful for the driver are available at the same time, it is needed to regulate the information flow, especially taking into consideration the riding...
mental workload and maneuver demand. In order to accomplish this project and usability requirement, the HMI Manager handles the communication-flow between the rider and the motorcycle in order to keep the distraction as low as possible, by developing highly intuitive information stimuli delivered in a safe way.

5 CONCLUSIONS
This work explains the whole path the data follow: from the environments cues captured by sensors to a highly meaningful message delivered to the driver. This path foresee the following steps: data acquisition, logic architecture and sensors definition, the data processing and the final output to the rider.

The PTW domain is undiscovered and full of difficulties, but these are the reasons why it is promising and challenging both for functionalities and HMI. SAFERIDER project is still on progress, as well its module, and it will be finalized in the next months. Its findings will pay the way for a future implementation of on-board functionalities which don’t exist in the global market yet.

REFERENCES
Agneta Sjögren PReVENT - INSAFES Project, “SP Deliverable 60/10 Final Report”;
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Abstract

Many areas in the world have been and are possible to be affected by severe physical disasters, like earthquake, tsunamis, hurricanes, etc; whereas fire and floods usually occur as immediate results of these incidents. Fires with the most serious consequences (fires involving injuries, fatalities or extensive material damage) have mostly been the result of tunnel accidents (12 out of the 14 worst fires known worldwide). Over 200 people have died in Europe as result of tunnel fires in the last decade. Another major difficulty that is imposed in planning the logistics of private and public transport is the effect of a catastrophic earthquake. Moreover, terrorism is unfortunately a reality of our days, for several European countries. Highly selected targets are subways/trains and other PT terminals, but also bridges and tunnels.

SAVE ME project, comes to give solution to the above problem. It aims to develop a system that detects natural and man-made disaster events in public transport terminals / vehicles and critical infrastructures (i.e. tunnels, and bridges) and that supports quick and optimal mass evacuation guidance, to save the lives of the general public and the rescuers, giving particular emphasis to the most vulnerable travellers (i.e. children, elderly and disabled). Its target application areas cover any PT vehicles station, hub and special transportation infrastructure (tunnel, bridge…). The focus group are all passengers, including elderly, disabled, children, and, in general the most vulnerable traveller groups. Apart from the travelers, the needs of other stakeholders are to be examined within the project, namely the professional rescue crews and the infrastructure/emergency units operators.

The project work starts with a thorough benchmarking on relevant technologies, algorithms and policies, to be taken into account in the formulation of early specifications for SAVE ME system, as well in the extraction of the use cases and application scenarios. An overview of the main, preliminary results arising from the benchmarking, is presented in the paper, together with generic specifications of the SAVE ME system.
1. INTRODUCTION

SAVE ME project, co-financed recently by the EC, develops technologies (algorithms, models, DSS) and an intelligent system (integrating intelligent sensors, infrastructure communications, interfaces to nomad devices and VMS/VDS, using intelligent agent technologies) to protect all travellers from physical disasters and terrorist attack related risks; with emphasis to the most vulnerable ones (such as elderly, children, disabled).

An innovative and open ontological framework will be developed for hazard recognition, classification and mitigation in transportation related disasters. Development includes new algorithms, interfaces and intelligent agents, that will give to SAVE ME its “intelligence”. The influence of stress, panic and other emotions on human behaviour will be researched (in relation to all SAVE ME traveller groups, disaster types and taking into account the system feedback). In addition, the appropriate disaster detection and analysis system is to be built in the form of a wireless sensor network grid, that supports detection of the disaster, localisation of travellers in the disaster area and follow-up of their movements, collection of key environmental data (i.e. on temperature, smog, etc.), communication to the operator’s centre of all measured data and interface to any existing databases (i.e. of the PT regarding the number of passengers on-board). The Decision Support System (DSS), seen as the ‘heart’ of SAVE ME, is based upon existing simulation and modelling tools (modified, to include vulnerable travellers data), which will be enhanced to a dynamic and closed-loop system, recalculate the situation constantly. According to DSS output, a wide range of Emergency Support measures is implemented, including interfaces for the infrastructure operators, the rescue team members, the citizens (both personalised at their mobile phones and generic through infrastructural elements). Finally, proper training of operators, rescue team and travellers are also to be developed.

All the above modules, systems, and measures (including training) are to be thoroughly tested in two sites, at a metro platform, vehicle and station of NEXUS in Newcastle (UK) and the very long tunnel of Gotthard (Switzerland), in order to assess their reliability, usability, user acceptance, economic and safety/security impacts.

2. PRELIMINARY RESULTS OF SOA ON SAVE ME RELATED TECHNOLOGIES AND FIRST SYSTEM SPECIFICATIONS

Among the first steps of the project execution is a benchmarking of existing systems, equipments and algorithms, worldwide, as well as the current policies, plans and tactics that are followed by various professional rescuers in emergency situations. The aim is to conclude on the desirable functionality and appropriate hardware and software characteristics of the SAVE ME system and modules and to identify market sensors and components that can be interfaced or/and integrated to SAVE ME system. For this reason, different areas falling into SAVE ME architecture and functionality have been reviewed and analysed. Preliminary main results are presented below per area, along with early system specifications. These areas cover well all the individual components and modules of SAVE ME system, as listed below:
- Systems/models assessing human behaviour in emergencies in transportation hubs and vehicles
- Emergencies detection and communication systems in transport hubs and vehicles
- Environmental detection sensors
- Localization sensors
- Telecommunication infrastructure
- Simulation and modeling tools
- Algorithms for guidance
- Decision support systems for emergencies support in transportation hubs and vehicles

2.1 Systems/models assessing human behaviour in emergencies in transportation hubs and vehicles

A review of the literature regarding modeling human behavior reveals three major trends in crowd simulation:

- The motion of crowds at a macroscopic level is similar to the flow of fluids.
- Model of a network of cells and base the state of a cell on the states of the immediately surrounding cells.
- Each pedestrian is considered as an individual entity and the interactions with the other pedestrians are individually modelled according to physical or social laws. The majority of the literature points this trend.

Several models are available (EESCAPE, EGRESSPRO, EGRESS, SIMULEX, EXODUS, etc.) that are based on the three simulation approaches (Santos & Aguirre, 2005).

The major trends in crowds simulation are applied mainly to model the behaviour of a large number of people in life-threatening situations, aiming to develop systems and training procedures that will be used to either minimize casualties due to crowd stampede induced by panic, or for crowd control by police and military authorities.

After studying the details of the proposed 3 simulation trends, the one to be adopted within TRAIN-ALL is the first. This is chosen, as the generic model can be adapted in order to:

- Cluster the users in different groups; i.e. instead of a homogenous behaviour (speed, mobility) of all travellers, to have additional clusters for elderly, wheelchair, blind, children, etc.
- Modify dynamically the behaviour model by fusing real situation data and restarting the calculation, based on the new data.
- Diversify the behaviour of the humans in the model depending on the emergency type, taking into account latest developments on stress, emotions and behaviour after a terrorist attack, a fire or an earthquake.
- Include the impact of the feedback provision (information, guidance) to the people on their behaviour and then modify the model accordingly.
2.2 Emergencies detection and communication systems in transport hubs and vehicles

Advanced emergency detection and evacuation systems for transport hubs generally comprise a variety of sensors spatially distributed on each critical point for detecting any emergency condition; additionally, a set of emergency signaling units is respectively located adjacent to emergency exits, and a control panel, comprised of a number of indicators, connected to emergency condition detectors, are parts of these systems. Furthermore, these emergency systems are interconnected with an emergency centre, able to provide support.

Recent advances in sensor technologies make possible to install and interconnect tiny devices within existing infrastructure, such as smoke detectors or overhead lighting, for networked use in case of an emergency. These networks can provide emergency control centers with 3D building visualization, real-time monitoring of hot spots or structure failures, and tracking of victims and personnel.

Yet, despite the increasing reliability and resiliency of modern telecommunications networks to physical damage, the risk associated with communications failures remains serious because of growing dependence upon these tools in emergency operations. Deploying wireless communications is typically among the first priorities in any emergency response, rescue, or relief situation.

Except for satellite communications, emergency services rely on public radio networks, like GPRS for data communications. Sometimes in disaster situations, even GSM is used for voice communication between relief workers. However, in case of emergency the public networks may get overloaded. So, the use of generally available public networks is not considered to be reliable enough for emergency situations. Moreover, GSM/GPRS is an infrastructure-based network, highly susceptible to disasters in small and medium sized areas. However, modern telecommunications infrastructure has also provided powerful and flexible tools to enable cities to cope with crisis, and quickly relocate and restore displaced or disrupted social and economic activities. The Internet, mobile telephony, and satellite communications provide unprecedented communications capabilities to a wide range of institutions and communities in disaster areas.

One of the ways SAVE ME will progress beyond state of the art addressing these challenges will be through the use of automated-notification technology, which can rapidly distribute information to large numbers of people. In order to avoid human driven errors (such as sending incorrect messages or failing to notify the right parties) and reduce them to a minimum, SAVE ME will provide extensive training and conduct regular testing. To be effective, the SAVE ME crisis-communication plan will anticipate and overcome potential obstacles such as power outages and downed phone lines.

As for localisation, there are many different methods and technologies available for localising a vehicle or a person. The most common is Global Positioning System (GPS), which is widely available. Such a system requires a line-of-sight to four or more satellites. This is not possible in a tunnel environment and may be less than perfect in some transport hubs or vehicles, depending on the urban structure.
The most appropriate method to define a position within a tunnel is Dead Reckoning (DR). Dead reckoning is a localisation method which does not require continuous connectivity to satellites, anchor nodes or a network.

Indoor position estimation is not a trivial task due to the absence of GPS signals. An additional system must be deployed in the observation area in order to be able to calculate position of objects or humans. Several technologies exist that can realize such systems and most of them are based on measuring a parameter that varies with distance from known and stationary reference points and then triangulating in order to estimate the unknown position.

A WiFi network can be used to estimate a position (Ladd et al. 2004; Bahl and Padmanabhan, 2000). Based on the position of the WiFi hotspots and a range-based or range-free localisation algorithm, a position can be estimated (He et al., 2003). The advantage of a WiFi network is that communication in both directions is possible. This opens the possibility to a wide range of new applications to improve the service and increase safety in tunnels or underground stations.

Indoor position estimation is not a trivial task due to the absence of GPS signals. An additional system must be deployed in the observation area in order to be able to calculate position of objects or humans. Several technologies exist that can realize such systems and most of them are based on measuring a parameter that varies with distance from known and stationary reference points and then triangulating in order to estimate the unknown position. A hybrid localisation system is able to combine information from the GSM network, radio beacons, WiFi hotspots, sensor networks and GPS (at the entrances) to provide position information with a high accuracy.

Other technologies for tunnel / underground stations localisation are based on infrared beacons (Want et al., 1992), RFID (Kourogi et al., 2006), Bluetooth (Aalto et al., 2004), Ultrasonic (Priyantha et al., 2000) or sensor networks (Lorincz and Welsh, 2005).

SAVE ME will use Wireless Sensor Network (WSN) technology, combined with hybrid localisation techniques, as this:

- is of low power;
- has communication capabilities;
- has (limited) computational capabilities;
- has sensing capabilities (accelerometer, microphone, cameras);
- has signalling capabilities (although limited, due to power constraints);
- offer local decision possibility, in case of communications failure;
- has localisation functions.

2.3 Decision support systems for emergencies support in transportation hubs and vehicles

Past experience has demonstrated that there exist two main hindrances for the evacuees to reach a building evacuation: (1) inappropriate selection of escape pathways and (2) congestion along the safest pathways (Lovas, 1998). Instructions generated for the specific circumstances leading to the need for the evacuation can lead to significant improvements in escape pathway selection. Moreover, explicit consideration of the number of people that such pathways can support in developing
real-time evacuation instructions can lead to reduced congestion throughout the building and greater likelihood of successful egress.

Spatial Decision Support Systems (SDSS) are explicitly designed to provide the user with a decision-making environment that enables the analysis of geographical information to be carried out in a robust, yet flexible manner. Fundamentally, SDSS involve the coupling of GIS and analytical/decision models to produce systems especially able to cope with spatial problems. They are designed to aid in the exploration, structuring, and solution of complex spatial problems such as the evacuation process (De Silva, 2000) describes a typical SDSS as having four components:

1. Analytical tools enabling data investigation;
2. Decision models enabling scenario based investigations;
3. A geographic / spatial database enabling storage and analysis of geographic information;
4. A user interface providing easy access to components 1, 2, and 3, as well as an attractive and comprehensive display of the output.

Similar to the general constituents of a SDSS proposes a GIS-Based Spatial Decision Support System for emergency services for London’s King’s Cross St. Pancras underground station (called KXSDSSES). It will couple current pedestrian egress simulation programs with the network analysis and route optimisation to evaluate, revise, and contribute to emergency services preparedness of a major disaster within the London King’s Cross redevelopment.

Along with this research line, the CAPEVACUATION project presents an emergency evacuation system for corridor traffic control within the Washington metropolitan area, which integrates both optimization and macroscopic/microscopic simulation methods. The system features integration of multiple functional modules. Its optimization module tries to identify the optimal control strategies during an evacuation based on a cell transmission formulation of network flows. The output module embedded with a macroscopic simulator allows users to evaluate various control strategies by providing key statistics as well as the visualization of the evacuation operation. System users can easily identify the potential bottlenecks and take necessary adjustment with the user-friendly input and output interface. The proposed system can facilitate system users to find effective evacuation control strategies in a large-scale network or in real-time operations, which is especially critical when unexpected events occur during the evacuation and the implemented plan needs to be revised in a timely manner. The application scenario is an attack at Union station, which is the transportation hub as well as the most visited destination in the Washington D.C.

Several other projects dealt with research and development in simulation, optimal routing and guidance (i.e. CROSSES and CROWD-MAGS).

Similarly to the above, the Dutch government has started a research project ‘Floris’ (Flood Risk and Safety in the Netherlands) to calculate the risks of about half of the 53 dike-ring areas of The Netherlands. This project has four tracks: (1) determining the probability of flooding risks of dike-rings areas; (2) the reliability of hydraulic structures; (3) the consequences of flooding and (4) coping with uncertainties.
As part of the third track, the consequences of flooding, the Ministry of Transport, Public Works and Water Management has asked the University of Twente to develop a Decision Support System for analyzing the process of preventive evacuation of people and cattle from a dike-ring area. This Support System, named Evacuation Calculator (EC), determines the results of several kinds of traffic management in terms of evacuation progress in time and traffic load. The EC makes a distinction between four types of traffic management scenarios: (1) reference; (2) nearest exit; (3) traffic management; (4) out-flow areas. The scenarios one and two represent a situation where no traffic management or limited traffic management is present. Scenario three (traffic management) calculates an optimal traffic management (given the model assumptions). Within the fourth scenario the user has the freedom to adjust the scenarios by (re)defining out-flow areas. In this way the user has the possibility to adapt to local possibilities and restraints.

Targets in the EC development were twofold: (1) a safe estimate of the evacuation time and (2) to support the development of an evacuation planning. Optimization methods were developed to solve the problems and meet the objectives. Even though the problem that was tackled is different from the one that is investigated in SAVE ME, similar techniques on the development of the DSS for the optimal route planning could be applied by changing the affecting parameters, such as topology and population element characteristics.

The SAVE ME DSS will be the core intelligence of the system. The SAVE ME DSS will be based in much more advanced, inclusive and dynamic models and will involve all stakeholders (operators but also emergency support units), in a closed-loop form. The DSS will fully support the common ontological framework for hazard recognition, classification and mitigation that will be developed in SAVE ME, to implement the interfaces with all other modules. The DSS will also receive as input behavioural modelling data for crowd simulation. Concerning the core of the DSS, SAVE ME will examine both pre-computed and dynamically generated and personalised path planning. It will also support dynamic grouping structure for crowd simulation modelling in emergency situations. Individuals will be targeted through their mobile phones while groups will receive information through situated displays and voice messages (conflicting information on the displays and the mobile device may create confusion). Real-time (dynamic), fast and reliable routing is also necessary in order to take into account sensorial and communication infrastructure damages, and possible structural changes that may have occurred during the event, making escape routes inaccessible.

2.4 Guidelines and training schemes for emergencies in transportation hubs and vehicles

When an intervention of crisis management is needed, the possibilities to inappropriate manage or create a worst situation because of human error and inadequate team competence are particularly high. Examining previous accidents, researchers have identified that possible individual errors are, for example, inadequate situation assessment, weak leadership, erroneous decision making, blind adherence to procedures and adverse stress reaction. Whereas for teamwork errors, role ambiguity resulting in tasks, lack of explicit co-ordination and communication problems are
included. Then, a good co-ordination of actions, an efficient communication within, between and across teams and a high level of decision making, sometimes under high level of stress, is needed to obtain an effective emergency management by large scale and complex organizations.

Therefore relevant training issues involve both technical and non-technical (i.e. social and cognitive skills). Using a point of view from psychology, such issues can be solved by an effective and efficient decision making, an accelerated proficiency and the development of expertise in individual and team activities. Across industries, training for emergency management consists of classroom-based training, manuals and emergency exercises. Unfortunately these kinds of methods have not always complete success and lack in improving the non-technical knowledge.

During the last two decades, further traditional training methodologies, i.e. cognitive and behavioural methods and new techniques, are gaining importance to increase knowledge, skills, and/or attitudes toward specific job dimensions. Three of the recent techniques are Crew Resource Management (CRM) method and Tactical Decision Game (TDG), assessment center methodology. Crew (or Cockpit) Resource Management (CRM) training originated from a NASA workshop in 1979 that focused on improving air safety. This training tries to solve one of the most relevant causes of human error, i.e. the failures of interpersonal communication, leadership, and decision making in the cockpit (first application is in aviation domain). A variety of CRM models have been successfully adapted to different types of industries and organizations, all based on the same basic concepts and principles. The primary goal of CRM is enhanced situational awareness and it recognizes that a discrepancy between what is happening and what should happen is often the first indicator that an error is occurring (O’Connor and Flin 2003). CRM is an effective type of training for teams which only come together in response to an incident or situation, as occurs in an industrial emergency management organisation. There are two benefits in CRM training: an improvement of human performance and teamwork in order to minimise the risk of emergencies or accidents occurring, and support to the teams to more efficiently perform once an emergency has occurred (Flin 2001).

The second training methodology aims to develop and improve intuitive decision making and related skills in complex, hazardous, real-world environments. TDGs act as a substitute for actual experience and provide a suitable, yet low-fidelity, opportunity to enhance skill development and expertise. Training in decision skills, through identification of the decision requirements and doing exercises with tactical decision games, has been found to boost expertise in decision making and judgment (Klein 1998). Normally, a TDG training session consists of one prepared scenario that is presented by a short text (2 or 3 paragraphs) that a facilitator reads aloud to the participants. Sometimes a “map” of the environment where the scenario is played is given to the participants. The purpose of the ‘story’ is to provide a background to the situation, however, some of the information given may be inadequate, misleading, or extraneous, moreover, the scenario always culminates in a dilemma. The requirement is that a plan to solve the incident is formulated. A great strength of TDGs is that the used scenarios allow sampling alternative task strategies, to compile an extensive experience bank, and to enrich experiences.
Finally, the third training methodology is the assessment center’s one. The purposes of this methodology are in three areas: (1) consolidate the tacit knowledge, i.e. the implicit knowledge that an individual learns from experience, improve (2) situation awareness and (3) self-efficacy and encourage an influence behavioural change through the quality of feedback that assessment center activities give. Assessment centres involve participation in multiple exercises and simulations, and the observation and evaluation of performance against predetermined tasks related behaviours by a team of trained assessors. These experts use an assessment process based on a combination of exercises and methods derived from analysis of tasks and operating contexts. A key aspect of assessment centre effectiveness is its use of simulation. Simulations leave opportunities to practice dealing with high pressure situations in a safe and supportive environment and to develop, rehearse and review technical and management skills under realistic circumstances (Paton, 2003).

The successful deployment and operation of an emergency response platform, like SAVE ME, relies heavily on the correct training of its operators but also on the assessment of its operation under simulated emergency scenarios. To this end, the SAVE ME platform will incorporate a Virtual Reality Training and Guidance System, that will simulate all aspects of the system’s operational features under realistic circumstances. Using these methodologies to training persons and teams, SAVE ME will achieve a real improvement in the emergency management, especially regarding knowledge and skills of infrastructure and rescue team coordinators. This causes a positive influence on the quality of the emergency interaction: better training limits the possibilities that an error occurs during facing a critical situation. Finally, special training infrastructure is used by rescue teams, where the personnel undergo regular trainings of new methods, scenarios and tools. Such a training facility is owned by CNVVF (SAVE ME partner) and it is located in Montelibretti, Italy. It has a road tunnel, with the possibility to instantiate realistic scenarios of fire and smoke.

3. CONCLUSIONS

Nowadays the technological efforts aim to prevent disasters and accidents before they occur, but this is not always possible and when one of the occurrence happens, it is extremely important that people, who should cope with it, have the right skills, knowledge and training to efficiently manage the problem.

SAVE ME takes an integrative approach, linking human behaviour modelling and prognosis and emergency support measures through specific interfaces to and training of operators, emergency teams and travellers with preventive, passive and active sensors in the infrastructure and the vehicles; in an integrated monitoring, rescue and crisis management system. Disaster avoidance and mitigation is considered as a holistic event, involving the infrastructure/ vehicle operator, the rescue team and the equipped and non-equipped travellers; including the most vulnerable ones.

For the above achievement, a detailed look of the existing systems and services is needed, to built upon them and extend them according to the needs of SAVE ME. Thus, a relevant benchmarking of marketed products, services, technologies and policies was among the first worksteps in the project, aiming to conclude on the
generic desirable functionality and appropriate hardware and software characteristics of the SAVE ME system and modules

4. REFERENCES


Contents session 5  Modelling

Modelling the Safety of Intersections
Dr Majid Sarvi, Department of Civil Engineering, Monash University, Australia

GRSI-Beijing Project of Improving Vulnerable road Users (VRU) Safety at Intersections
Yanyan Chen, Beijing University of Technology, China

Measuring the Risk of Road Crashes
Aline Chouinard, Transport Canada, Canada

Bringing Structure into Road Safety Evaluation: A Hierarchy of Indicators
Tom Brijs, IMOB – Hasselt University, Belgium

Road Safety Evaluation and Target Setting using Data Envelopment Analysis
Tom Brijs, IMOB – Hasselt University, Belgium

Evaluation of Methods for Pedestrian Safety Improvement on Left-Turning Vehicles Movement
Hassan Zoghi, Islamic Azad University, Karaj Branch, Tehran, Iran

Multilevel Data In Traffic Safety: a 5xST-level Hierarchy
Helai Huang, University of Central Florida, USA
MODELLING THE SAFETY OF INTERSECTIONS

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ABSTRACT
This paper presents a framework for assessing the level of safety at an intersection. The developed methodology is based on a Safety Analysis CHain (SACH) which has five segments including the traffic flow, number of conflicts, severity of conflicts, number of crashes and severity of crashes at an intersection. Three models are proposed to quantify the segments of the SACH. Traffic simulation has been utilised to model the number and severity of conflicts at an intersection. A numerical simulation model looks at each conflict and the human behaviour in the conflict to investigate the characteristics of the crashes. A severity model has been used to determine the severity of the measured crash characteristics. In the developed methodology the foregoing models run consecutively to represent the five segments of the SACH. Two measures, the Casualty Crash Risk of a Manoeuvre (CCRM) and the Danger Index for a Manoeuvre (DIM) in an intersection, are derived to represent the safety performance of intersections. The CCRM represents the safety performance of intersections considering all segments of the SACH. The DIM is derived to give an indication of the main transportation related parameters increasing the severity of crashes. The methodology was applied to an uncontrolled four leg intersection. The framework outlined offers potential for proactively studying and comparing the safety performance of different intersection designs. Further research is required to look at the probability of a crash and the measures of the behaviour of drivers in intersections.
1 INTRODUCTION
Improving the safety of the road system is one of the most important health issues in today’s society (Ogden, 1996; Evans, 2004). Improvements in road infrastructure, vehicle design, education programs and road regulations aimed at safety all contribute to the steady reduction in road fatalities and serious injuries in many countries. However, traffic and the desire for mobility continue to increase and accidents continue to occur (Evans, 2004).

Data on vehicle crashes suggest that intersections are associated with a higher level of crash risk than other types of facilities in the road network. Generally, intersections show a concentration of many types of frequently occurring conflicts, create threatening angles of impact and bring together a diverse range of road user types and competing demands (Wong et al. 2007; Abdel-Aty and Keller, 2005).

As safety levels of the road system improve, it is necessary for the methods used to reduce road crashes to become more sophisticated. Consequently, the analysis of countermeasures requires a deeper understanding of the mechanisms involved in the crash and correspondingly more sophisticated analysis procedures. Fortunately, improved technology is providing opportunities to develop these procedures. This paper presents a modelling framework that provides an assessment method for evaluating intersection safety levels and a method to diagnose the crash characteristics that increasing the risk of being involved in severe crashes.

The paper will briefly review the research on intersection safety evaluation. It then presents the development of a methodology to assess the safety level of intersections. A case study of the methodology is outlined. The paper closes with suggestions on future research.

2 BACKGROUND OF THE RESEARCH
Safety in the transport system is the consequence of an interaction between the driver, the vehicle and the road environment (Ogden, 1996). Modelling of this interaction in the past has generally focused on two distinct directions, either primarily focusing on the vehicle or on the transport system. In both cases the driver is the centre of the system, making decisions and bearing the consequences of these decisions.

Considerable research has been directed at modelling vehicles and the severity of collision interactions between vehicles and other objects. These models tend to focus on the interaction between vehicles and/or vehicles and road side objects. They describe the vehicle to vehicle (or object) interaction in considerable detail. Jacques et al. (2003) describes three types of models that have been used to measure such situations. Gross Motion Simulators (rigid body dynamic models) replicate the bodies (vehicle, person, object etc) involved in the crash situation by using a set of rigid bodies, usually elliptical in shape, connected by various types of joints. These models are primarily used to examine the dynamics of the crash test dummies involved in a crash, with the vehicle usually assumed to be rigid. The Mathematical Dynamic Model (MADYMO) is a commonly used model of this type. Energy-based programs replicate the interaction between vehicles (and/or) objects estimating the energy involved in the interaction. They predict the outcome of collisions using a set of estimated parameters which are related to properties of the vehicle and road. The Human, Vehicle, Environment (HVE) software is an energy-based program which can simulate the crash situation in details and estimate the trajectory of each vehicle after the crash in order that the severity of the crash can be measured (Jacques et al., 2003; Engineering Dynamics Corporation, 2006). Finite Element Programs have been used to replicate the objects involved in a crash in great detail. Each body is replicated by a complex mesh of triangles. LS-DYNA, PAM-CRASH, Radioss, and MSC-Dytran are some of the commonly used finite element programs. These models tend to take the traffic system as given and analyse the outcome of particular crash scenarios.
Other researchers have approached the safety issue from the traffic system side, considering crash involvement, as opposed to crashworthiness. Initial models of the traffic system focused on the traffic flow in particular directions and determine the level of conflict. Studies (Golob et al., 1998; Turner and Nicholson, 1997) have been carried out to look at the level of vehicle interaction at intersections, relating the approach volume to the number of accidents.

Another approach to modelling traffic accidents is to develop statistical relationships between the various variables resulting in the crash (Chin and Quddus, 2003; Yan, Radwan and Abdel-Aty, 2005; Wang and Abdel-Aty, 2008). These researchers used regression and/or ordered probit models for analysing driver injury severity level at intersections (Abdel-Aty, 2003, Abdel-Aty and Keller, 2005).

The previous approaches have tended to use crash data as the basis of their analysis. The lack of such data, its slowness in being collected and the difficulty in observing some accident situations, encouraged researchers to look at other approaches. One such approach grew out of the conflict analysis literature and considered surrogate safety measures for indicting the safety of facilities (FHWA, 2003). A traffic conflict has been defined as:

‘An observable situation in which two or more road users approach each other in time and space to such an extent that there is risk of collision if their movement remains unchanged’ (Amundsen and Hyden, 1997).

Hyden (1987) defined uniform severity level and uniform severity zones for measuring the severity level of the conflicts regarding time-to-accident and conflict speed. Hyden (1996) defined different conflict levels according to different required braking rates (RBR) (or Deceleration Rate). He defined the four conflict levels summarised in Table 1.

Table 1: Different levels of required braking rate (Hyden, 1996)

<table>
<thead>
<tr>
<th>Conflict Level</th>
<th>Deceleration-to-Safety</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Conflict</td>
<td>Braking Rate &lt;= 0 m/s²</td>
<td>Evasive action not necessary</td>
</tr>
<tr>
<td>No Conflict</td>
<td>Braking Rate 0 to -1 m/s²</td>
<td>Adaptation necessary</td>
</tr>
<tr>
<td>1</td>
<td>Braking Rate -1 to -2 m/s²</td>
<td>Reaction necessary</td>
</tr>
<tr>
<td>2</td>
<td>Braking Rate -2 to -4 m/s²</td>
<td>Considerable reaction necessary</td>
</tr>
<tr>
<td>3</td>
<td>Braking Rate -4 to -6 m/s²</td>
<td>Heavy reaction necessary</td>
</tr>
<tr>
<td>4</td>
<td>Braking Rate &lt; -6 m/s²</td>
<td>Emergency reaction necessary</td>
</tr>
</tbody>
</table>

Recently, Archer and Young (2009), Cunto and Saccomanno (2008), the FHWA (2008), Davis (2007) and Davis and Morris (2009) have made significant steps forward in incorporating the traffic conflict approach into traffic simulation models in order to estimate the number and type of crashes. Archer (2005) studied the application of surrogate safety measures for intersection safety assessment and their application in micro-simulation modelling. He used a probability approach for developing a gap acceptance model for unsignalised T intersections in order to determine the number and severity of conflicts. In this research, the probabilistic gap acceptance model is developed using binary logistic regression. The surrogate safety measures used for this research are Time-to-Accident (TTA), Time-to-Collision (TTC), and Post Encroachment Time (PET). The severity of the conflicts is measured, using Hyden’s (1996) definition regarding the required braking rate (RBR) for each
conflict. The micro-simulation tool selected for this research was VISSIM since this has been used in a number of other road safety applications. Cunto and Saccomanno (2008) developed a methodology for intersection safety evaluation using micro-simulation. He used VISSIM simulation software for his study. He defined a crash potential index to assess the safety performance of intersection. Further research which considers intersection safety evaluation was undertaken by the Federal Highway Administration (2008). They developed surrogate safety assessment model (SSAM) for assessing the safety performance of different types of intersections. In order to do this they developed software which supports traffic simulation models including VISSIM, AIMSUN, PARAMICS and TEXAS. The SSAM model can find the number and severity of conflicts in each conflict point at an intersection. Based on the assumption that the severe conflicts will lead to accidents, they measured the severity of accidents by calculating the speed difference of vehicles in the accident (ΔV). The surrogate safety measures used by this model are: Minimum time-to-collision (TTC); Minimum post-encroachment time (PET); Initial deceleration rate (DR); Maximum deceleration rate (MaxD); Maximum speed (MaxS); Maximum speed differential (ΔS); Classification as lane-change, rear-end, or path-crossing event type; and Vehicle velocity change had the event proceeded to a crash (ΔV).

All the above modelling approaches add to the knowledge of road crashes. There is a clear need to combine these modelling approaches to enable the entire crash system to be analysed.

3 A NEW METHODOLOGY FOR MEASURING INTERSECTION SAFETY

3.1 Safety Analysis CHain (SACH)
The previous discussion pointed the need for a modelling approach that replicated the entire crash process. Such an approach requires the five segments in a “Safety Analysis CHain” (SACH) (see Figure 1) to be defined.

![Figure 1: The Safety Analysis CHain (SACH)](image)

In order to evaluate the safety performance of each part of the road network in terms of the number of severe crashes, a model should be developed which considers all the segments of the SACH. In turn, the safety performance of the road network can be judged in terms of the segments in the chain which take place and make the intersection unsafe. To implement the SACH methodology, traffic micro-simulation is chosen to model the first three segments of SACH (Figure 1). The last two sections will be modelled by a numerical simulation model and a severity model respectively. The modelling methodology suggested to enable the quantifications of the SACH has three main parts (See Figure 2):

1. Estimate the number and severity of conflicts using micro-simulation model.
2. Estimate, the number and characteristics of crashes using a numerical simulation model.
3. Develop a model (severity model) to estimate the probability of being involved in a fatal and serious injury crashes regarding crash characteristics.
3.1.1 Traffic flow, number and severity of conflicts
The first part was outlined in the previous section and is based on the traffic simulation carried out by Archer and Young (2009), Cunto and Saccomanno (2008) and the FHWA
(2008). It focuses on the first three segments of the SACH. This Part has three steps: determining the characteristics of the intersection, using micro-simulation software for modelling the intersection, and estimating the number and severity of conflicts.

3.1.2 Numerical simulation model for crash simulation:
The second part of the methodology is related to the fourth segment of the SACH. In order to determine whether a conflict will lead to a crash, a more detailed consideration should be undertaken for the main factors affecting the crash to occur. The approach considered for modelling the fourth segment of SACH is focusing on the possible crashes which can occur in regard to the conflict characteristics. That is, a population of crashes which can occur based on the conflict characteristics is simulated and the characteristics of these crashes are determined.

In order to estimate the characteristics of possible crashes, an additional analysis process needs to be developed to simulate conflicts resulting from the different assumptions about the driver behaviour in conflict and road conditions. Each assumption represents an individual ‘conflict event’; so that, each conflict has a number of conflict events represented by taking different assumptions for the conflict. The number of conflict events leading to a crash is determined for each conflict. Each conflict will have a number of crashes and each crash has a set of characteristics representing the severity of the crash. In the numerical simulation model the following steps will be carried out:

**Step1** - Simulate each conflict in the numerical simulation model using the characteristics of conflicts from the output of the micro-simulation software. There are distributions for velocity, distance, mass, and deceleration rate of the vehicles involving in conflicts. For measuring the conflict characteristics RBR and velocity can be worked out randomly according to their distributions. The distance of the vehicles from crash area can be calculated regarding the relationship existing between the RBR, Speed and distance. This relationship can be obtained from the micro-simulation model. Thus, the conflict situation is replicated at this step.

**Step2** - Time to Collision (TTC) of the conflict is divided into a number of time steps. For the first time step two reactions are considered for the driver who has the priority. The first reaction is that the driver reacts to the conflict and pushes the brake pedal; so that, the simulation will continue to find out whether a crash occurs given this trajectory. The braking simulation is done based on the wet and dry conditions of the road pavement. The second reaction is that the driver continues its trajectory and does not react to the conflict at first time step. The driver may react to the conflict at the second time step; thus, the braking trajectory of the vehicle is simulated to indicate whether the conflict event will lead to crash. If the driver does not react to the conflict in the second time the vehicle continues its initial trajectory to reach the next time step. Therefore, at each time step the possibility of braking is considered and based on that the braking trajectory is simulated. The trajectory of the vehicle accepting a gap is constant during the simulation.

**Step3** - The simulation will continue until that time step in which one of the vehicles passes the crash area.

3.1.3 Probability of being involved in a casualty crash
The last segment of the SACH model is considered in this part. In consideration with the characteristics of occurred crashes the crash severity is represented using a severity model. Corben et al (2004) suggested that the kinetic energy (K) of crash is the key factor which represents the severity of crashes.

An empirical model was introduced by Evans (1994) to measure the severity of crashes as a function of the change in velocity of the subject vehicle during a crash event (ΔV). Evans
used real-world crash data from the National Automotive Sampling System (NASS) study to
develop a model categorising crashes as fatal or serious injury. Equation 1 shows the Evan’s
formula for estimating the severity of the crash as a function of $\Delta V$.

$$P_C = \left( \frac{\Delta V}{\alpha} \right)^k \quad \Delta V \leq \alpha$$

$$P_C = 1 \quad \Delta V > \alpha$$

Where:

- $P_C$: Probability of being involved in a casualty crash
- $\Delta V_t$: Speed difference of the vehicle during the crash,
- $\alpha$: Minimum $\Delta V$ which causes serious injury or fatality, and
- $k$: Parameter of the model.

For fatalities: $\alpha = 69.18$ miles/h $\quad k = 4.57 \pm 0.25$

For serious injuries: $\alpha = 67.43$ miles/h $\quad k = 2.62 \pm 0.17$

Although Evans’ (1994) relationship is used in the case study to follow, it should be noted
that it was developed on the basis of a vehicle sample manufactured between 1982 and 1991
and is therefore likely to be somewhat conservative in its estimates, given the improved
.crashworthiness of more modern vehicles. Also, the unit of $\alpha$ is changed from miles/h to
km/h for side crashes (Logan et al., 2009).

In order to calculate the speed difference ($\Delta V$) of the vehicles at the time of the crash, the
numerical model shown below established crash investigation techniques using the law of
Conservation of Momentum (see Logan et al. 2009). The model is as follows:

$$\Delta V_t = \sqrt{\left( \Delta V_t^x \right)^2 + \left( \Delta V_t^y \right)^2}$$

$$\Delta V_t^x = \frac{M_t \times \Delta V_t + M_b \times \Delta V_b \times \cos \beta}{M_t + M_b}$$

$$\Delta V_t^y = \frac{M_b \times \Delta V_b \times \sin \beta}{M_t + M_b}$$

Where

- $\Delta V_t^x$: $\Delta V$ of the target vehicle in X coordination in the crash (km/h)
- $\Delta V_t^y$: $\Delta V$ of the target vehicle in Y coordination in the crash (km/h)
- $M_t$: Mass of the target vehicle (kg)
- $M_b$: Mass of the bullet vehicle (kg)
- $V_t$: Speed of the target vehicle (km/h)
- $V_b$: Speed of the bullet vehicle (km/h)
- $\beta$: The angle of the accident

For reasons of simplification, the model assumes that there is minimal rotation during the
.crash event and that the centres of mass of the two colliding vehicles are coincident. This is a
reasonable assumption, because, in practical terms, it means that for most passenger vehicles,
the centre of the vehicle cabin corresponds to the centre of mass and injuries to occupants are
more likely at this location due to cabin intrusion.

3.2. New measures for assessing the safety performance of intersections
The Casualty Crash Risk for a Manoeuvre (CCRM) is the measure defined for estimating the level of safety for each manoeuvre in the intersection. The CCRM is defined as the risk of being involved in a casualty crash by taking the manoeuvre. This risk is equal to the addition of the probability of being involved in a casualty crash for each conflict point. There are number of conflict points for each manoeuvre. Conflict points are defined as the conflict area made by two manoeuvres crossing each other at intersection. For calculating the CCRM, the casualty crash risk for conflict points should be added. The CCRM is given by:

\[
CCRM = \sum_{n=1}^{N_{cp}} \left\{ \sum_{i=1}^{N_{con}} \left[ \left( \sum_{j=1}^{N_{n,i}} \left( p_{F}^{n,i,j} + p_{I}^{n,i,j} \right) \right) \times \frac{1}{N_{n,i}} \right] \times \frac{1}{Q} \right\}
\]

Where

- \( p_{F}^{n,i,j} \): Probability of being involved in a fatal crash calculated for each crash \( j \) and conflict \( i \) in conflict point \( n \).
- \( p_{I}^{n,i,j} \): Probability of being involved in a serious injury crash calculated for each crash \( j \) and conflict \( i \) in conflict point \( n \).
- \( i \): is a subscript representing a conflict
- \( j \): is a subscript representing a crash
- \( n \): is a subscript representing a conflict point
- \( Q \): Total number of vehicles taking the manoeuvre during particular simulation period.
- \( N_{n,i}^{cra} \): is the total number of crashes for each conflict \( i \) in the conflict point \( n \).
- \( N_{con}^{n} \): Number of conflicts in conflict point \( n \).
- \( N_{cp}^{n} \): Number of conflict points in the manoeuvre.
- \( N_{n,i}^{alts} \): Number of alternative simulation done considering different reactions taken by both vehicles for each conflict \( i \) in the conflict point \( n \).

A second performance measure, the Danger Index for Manoeuvre (DIM), is derived to determine whether the risk of being involved in a severe crash is decreased; Two types of DIM are defined based on the crash characteristics which are the geometry of the crash and the velocity of the bullet vehicle in the crash.

The Geometry Based Danger Index (GDIM) focuses on the crash geometry which represents the impacted part of the target vehicle and the impact angle of the crash. In the GDIM the worst situation is defined as the crash geometry in which the middle part of the target vehicle impacted by the bullet vehicle and the impact angle is 90°. According to the impact angle of the crashes, in which the middle part of the target vehicle is impacted by the bullet vehicle, each crash gets a GDIM value. The GDIM is calculated using the following equation:

\[
GDIM = \sum_{n=1}^{N_{cp}} \left\{ \sum_{i=1}^{N_{con}} \left[ \left( \sum_{k=1}^{N_{n,i}} A_{n,i,k} \right) \times \frac{1}{N_{n,i}^{cra}} \right] \right\}
\]

Where:

- \( k \): Is a subscript representing a crash which meets the GDIM conditions.
- \( N_{g}^{n,i} \): Number of crashes which meet the GDIM conditions in conflict \( i \) of
conflict point n.

\( \lambda^{n,i,k} \): Angle factor for crash k and conflict i in conflict point n.

Velocity based danger index (VDIM) considers the proportion of crashes in which the velocity of bullet vehicle is more than 50 km/h (Kloeden et al., 1997). The following equation is derived for calculating the VDIM:

\[
VDIM = \sum_{n=1}^{N_{cp}} \left[ \sum_{i=1}^{N_{gon}} \frac{N_{v}^{n,i}}{N_{v,crd}^{n,i}} \right] \sum_{k=1}^{90} \lambda^{n,i,k} \]  

\( N_v \): Number of crashes which meet the VDIM conditions in conflict i of conflict point n.

The DIM is an index representing the risk of the manoeuvre regarding the crash geometry and the velocity of the bullet vehicle in crash.

\[
DIM = \sum_{n=1}^{N_{cp}} \left[ \frac{\sum_{i=1}^{N_{gon}} \lambda^{n,i,k} \sum_{k=1}^{90} \frac{1}{N_{v,crd}^{n,i}}}{N_{v,crd}^{n,i}} \right] + \sum_{n=1}^{N_{cp}} \left[ \frac{\sum_{i=1}^{N_{gon}} N_{v}^{n,i}}{N_{v,crd}^{n,i}} \right] \]  

4 AN APPLICATION OF THE METHODOLOGY

In this section, a case study of the methodology, focusing on the intersection safety performance using VISSIM simulation model, is presented. The four leg unsignalised intersection between Victoria Road and Burke Road, Camberwell, Melbourne, Australia was chosen for the case study (Figure 3). The type of the intersection is a cross intersection controlled by stop sign in the approaches from Victoria Road. Information associated with the geometric design, the traffic volume and the origin destination matrix of intersection were collected from the site.

![Figure 3: Intersection layout](image)

The surrogate safety measure used for measuring conflicts is required braking rate (RBR). According to the definitions proposed by Hyden (1996) (See Table 1), a RBR of more than -4 (m/s^2) was considered as a serious conflict. In the developed model, the crash taken into
consideration is the side crash occurring between the vehicles giving way from Victoria Road (West to East) and the vehicles driving along Burke Road (South to North).

The measures used for measuring the safety level of the intersections are: the number and severity of conflicts, number of accidents, casualty crash risk for a manoeuvre (CCRM) in the minor and major street and danger index for a manoeuvre (DIM) in the minor street. The driver behaviour, in which vehicles driving on the major road and minor road are not aware of each other, is investigated. This situation considers the ‘do-nothing’ reaction for both drivers and represents the higher severity for crashes due to the higher impact velocity (Farmer et al., 1997).

The assumption of the numerical model developed by Logan et al (2009) is that the bullet vehicle impacts the target vehicle from the middle part; so that, in the calculation of $P_C$ it is assumed that the geometry of the accidents will meet the GDIM conditions. Therefore, the CCRM in minor road should be consistent with the VDIM as the GDIM condition for the crashes is the same.

The VISSIM simulation model was run for a one hour simulation period for three different minor traffic flows (6 veh/h, 20veh/h, 40 veh/h). This enables the safety performance of the intersection to be studied for three different situations. Ten runs of each simulation model were undertaken. The results of the model is summarised in Table 2.

<table>
<thead>
<tr>
<th>Conflict Type</th>
<th>Minor Flow 6 veh/hr</th>
<th>Minor Flow 20 veh/hr</th>
<th>Minor Flow 40 veh/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Conflicts</td>
<td>6.6</td>
<td>14.4</td>
<td>22.6</td>
</tr>
<tr>
<td>Number of Serious Conflicts</td>
<td>2.6</td>
<td>4.3</td>
<td>6.2</td>
</tr>
<tr>
<td>Number of Crashes</td>
<td>0.6</td>
<td>2.7</td>
<td>5.9</td>
</tr>
<tr>
<td>CCRM (Major)</td>
<td>3.36E-05</td>
<td>0.000293</td>
<td>0.000465</td>
</tr>
<tr>
<td>CCRM (Minor)</td>
<td>0.003715</td>
<td>0.009732</td>
<td>0.007726</td>
</tr>
<tr>
<td>GDIM (Minor)</td>
<td>0.2</td>
<td>0.32</td>
<td>0.45</td>
</tr>
<tr>
<td>VDIM (Minor)</td>
<td>0.4</td>
<td>0.79</td>
<td>0.68</td>
</tr>
<tr>
<td>DIM (Minor)</td>
<td>0.6</td>
<td>1.11</td>
<td>1.13</td>
</tr>
</tbody>
</table>

The statistical analysis (Levine et al., 2008) confirms that there is an upward trend in the total number of conflicts, serious conflicts and the crashes. This seems to be reasonable regarding the more conflicting manoeuvres occurring by increasing the minor traffic flow.

The CCRM of the major approach is increased by increasing the minor traffic flow. However, the results showed that the CCRM for minor approach with the traffic flow of 20 veh/hr is more than the CCRM of minor approach with the traffic flow of 40 veh/hr. It can also be seen that there is an upward trend in GDIM and overall DIM as the minor traffic flow is increased. On the other hand, the results show that the VDIM where the minor traffic flow is 20 veh/hr, is more than the VDIM in other situations. This confirms the consistency of the CCRM and the VDIM of the minor approach.

The results of the simulation show that although the number of conflicts and crashes has an upward trend, the severity of crashes for the vehicles moving in the minor approach is more where the minor traffic flow is 20 veh/hr. This issue put the safety performance of the minor
approach where the minor traffic flow is 20 veh/hr in the worst condition in comparison with the safety performance of the minor road in other situations.

5 CONCLUSION
This paper has presented a framework for assessing the safety level of intersections. In the developed methodology the safety analysis from transportation point of view and crash analysis point of view are combined together to replicate the entire crash process. A Safety Analysis CHain (SACH) is defined as the core of the theory. The five segments of the SACH, which are the traffic flow, number of conflicts, number of severe conflicts, number of crashes and the number of severe crashes at intersection, are quantified using three models: Traffic simulation has been utilised to model the number and severity of conflicts at an intersection; a numerical simulation model looks at each conflict and the human behaviour in conflict to investigate the characteristics of the crashes; and a severity model has been used to determine the severity of the measured crash characteristics. The Casualty Crash Risk for the Manoeuvre (CCRM) and the Danger Index of the Manoeuvre (DIM) has been defined to measure the safety performance of intersections and the main transportation parameters affecting the severity of crashes. The CCRM reveals the safety performance of intersection in regard with all segments of the SACH. The DIM is defined according to the geometry of the crash and the velocity of the bullet vehicle in the crash. The preceding factors increase the severity of the crashes and CCRM cannot consider their frequency. A case study of the methodology has been conducted to show the potential of the theory for representing the safety level of intersections. The methodology was applied to an uncontrolled intersection and the results of the model showed that as the minor traffic flow is added the safety performance of the major manoeuvre is decreased. However, the safety level of the minor approach is the lowest where the minor traffic flow is 20 veh/hr; because, the velocity of the bullet vehicles was higher in this condition.

The developed methodology offers considerable potential for proactively studying and comparing different intersection designs; particularly, where there is not enough crash data to analyse or there is a newly designed intersection which its level of safety is needed to be assessed. Further research is required to look at the probability of a crash and the measures of the behaviour of the drivers at intersections.

6 REFERENCES


GRSI Beijing Project of Improving Vulnerable Road Users (VRU) Safety at Intersections

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Abstract: According to the official statistics for Beijing during 2004-2005, over 50 percent of the crashes in the city occurred at the intersections, over 30 percent of crashes in the suburbs occurred at intersections and 43 percent of the crashes were related to VRU.

During 2006-2008, Global Road Safety Partnership (GRSP) carried out a 3-year project in Beijing to improve VRU safety at intersections. The key partners of the project include Beijing Transportation Research Center of Beijing Municipal Committee of Communications, Beijing University of Technology and Beijing Traffic Management Bureau (BTMB - traffic police).

The project was divided into 2 phases: phase I – the situational study; phase II – to implement the chosen countermeasures (constructions) and to conduct the before/after data analysis for effectiveness evaluation. Up to now, the project is nearly completed. Based on the before and after data analysis, it is found out that

- The traffic conflicts have been reduced at all selected intersections after taken the countermeasures;
- All road users especially the VRUs feel safer when crossing the intersections;
- To improve the road safety is not necessary expensive.

As a product of the project, a good practice manual is being developed by the local project team and it will be launched in 2009.

The fund for the situational survey and the outcome evaluation (before/after data analysis) was provided by Global Road Safety Initiatives (GRSI), one of the programs implemented by GRSP. The construction for improvement at the six selected junctions was paid by the Beijing Municipal Government.

1 Background

Of all issues that people face daily, road traffic crashes are one of the most complex and most dangerous. Worldwide, nearly 1.2 million people are killed on the road each year and over 50 million people are injured with many of them become disabled for the rest of their life. It is recognized that a high economic burden has been caused by road traffic crashes - 65 billion US dollars is the estimated cost in low and middle income countries. However, road safety issues have not attracted enough
attention from government and the media. The World Report on Road Traffic Injury Prevention [1] indicated that without appropriate action, road traffic fatalities are predicted to increase by 67 percent between 2000 and 2020, and in low-income and middle-income countries deaths are expected to increase by as much as 80 percent.

In the low and middle income countries including China, the majority of such deaths and injuries are among “vulnerable road users” (VRU) – pedestrians, cyclists and motorcyclists. Without sufficient safety facilities on the road, urban junctions are the places where many crashes and traffic conflicts occur. However, the VRU’s safety at the junctions has not been always considered sufficiently by people when planning cities or designing roads [2].

In the meantime, traffic efficiency is not satisfactory – congestion on the road is still serious. Therefore, besides ensuring safety for all road users, particularly the safety of pedestrians and cyclists, it is important to maximize road traffic efficiency.

Taking into account this background, Beijing Transportation Research Center (BTRC), Beijing University of Technology (BJUT) and Global Road Safety Partnership (GRSP) worked together on a project to improve vulnerable road users’ (VRU) safety at urban junctions in Beijing during 2006-2008. As a key output of the project, the team also prepared the good practice manual based on international and national good practice on VRU safety and experience gained from the project.

2 Objectives

- Focus on the high risk intersections in Beijing.
- Improve the VRU safety at the selected intersections by using low engineering cost countermeasures (channelization, barrier, pedestrian island, road signs, etc.).
- Provide a good practice guide for other cities in China.

3. Method

- Data collection and analysis

Data collection consisted of two parts:

a) collect and analyze the historical crash data

b) collect and analyze the traffic and behavior data of the selected junctions
• Data processing

EXCEL was used to show the information collected and to identify the key information; SPSS was used to statistically analyze the crash data, and to identify the correlation among indices in the crash.

• Traffic Conflicts Technique (TCT) \(^3\).

In this project, Prof. Christer Hyden’s (Professor of Lund Institute of Technology in Sweden) Traffic Conflicts Technique (TCT) was applied for both conflicts identification and the before/after evaluation.

For the process of conflicts identification at the junctions, the CDBASE software of Prof. Hyden was used (refer to the picture below). The system analyses the severity of conflicts after inputting the fixed indices.
• Using low cost engineering countermeasures (channelization, barrier, pedestrian island, road signs, etc.) for improvement.

• Using before/after data comparison to evaluate the effectiveness of the countermeasures used for the project.

Prof. Hyden’s Traffic Conflicts Technique (TCT) was also used to evaluate the efficiency of the countermeasures. TCT is a non-crash-based safety estimation method that addresses the issues of measuring safety. It produces a link between behaviors and accidents. It has 'one leg' on the behavioral side, via the continuous monitoring of behaviors and specification of behaviors that lead to a serious conflict. The 'other leg' is on the accident side, thanks to the identification of near-accident situations (=serious conflicts) that have proven to have a close relationship with accidents. It is judged a serious conflict using the chart in Fig. 1 below. The observer takes two indicators from the junction video. The two indicators are conflicting speed (the speed when road user take action to avoid crash) and TA-value (the time from the road user taking action to the crash happening, if road user has not taken action), if the point in this chart is above the curve, the conflict is serious conflict [3].
4. Activities

4.1 Data Collection and Analysis of the Historical Crashes

In China, there are mainly two types of road crash treatments:

a) General treatments
b) Simple treatments.

General treatments are taken based on the conditions of the crashes causing death and serious injury, or crashes causing great property loss. Simple treatments are taken usually based on the conditions of self-reported minor injuries and little property loss.

From 2006 to 2007 the crash data from Beijing Traffic Management Bureau (BTMB) was as follows:

a) The general treatment crash data during December 2003 to December 2005
b) The simple treatment crash data during January 2001 to March 2006

The general treatment crash data was used to identify the black point, and find the crash prone areas from them. Thereby, the materials are provided for the next step of designing the targeted
countermeasures to improve safety of vulnerable road user (VRU) at those high risk junctions and evaluate the effectiveness after the countermeasures taken. The simple treatment crash data for Beijing was used to analyze and evaluate the overall situation for VRUs safety on the road, and to understand the current VRU safety situation at junctions.

4.2 The on-site traffic data collection at the selected junctions

The collected data included:

a) The camera video records from Beijing Traffic Management Bureau (BTMB)
b) Traffic data from field investigation
c) Road user behaviors survey.

4.2.1 Data from BTMB include traffic volumes and speed at part of junctions

4.2.2 Traffic Data from Field Investigation

Based on the traffic data from BTMB, additional data needs were determined to be collected from field observations. The field investigation consists of on-site videos recording conflict numbers and the characteristics of road users, (the video films can be played repeatedly afterwards in order to collect the necessary information), and on-site data collection on traffic volumes, vehicle speeds, queuing length, geometrical parameters of junctions and the existing safety facilities at junctions.

4.2.3 Road User Behavior Survey

In order to understand the effectiveness of the countermeasures taken, a before and after behavior survey was conducted via site observation and a questionnaire for different kinds of road users at the selected junctions. The behaviors included two stage crossing of the left turn bicycles, pedestrians using the existing safety facilities (zebra crossing, refuge islands, overpass and underpass), and the compliance rate with traffic laws and people’s feelings of using those facilities. Depending on the situation, the sample size for each behavior varied from 50-200.

4.3 Site Selections
Based on the result of data analysis, and through the discussions between the local project team (BTRC, BJUT, GRSP) and Beijing Traffic Management Bureau (BTMB) six typical junctions were selected for improvement. The following factors were considered during the site selection:

a) The junctions that were high risk – the junctions had to be either the existing black spots or be with high numbers of serious traffic conflicts;

b) The location of the junctions – the location should not be too far away from the city

c) The type of the junctions – from a research aspect, different types of the junction were selected for the project.

The table below shows the general information of each selected junction.
<table>
<thead>
<tr>
<th>Name</th>
<th>Numbers of Casualty Crash</th>
<th>Type of Junctions</th>
<th>Existing Safety Facility</th>
<th>Main Crash Type at Each Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xidan</td>
<td>12</td>
<td>At-grade 4-leg interchange</td>
<td>underpass at north-south direction</td>
<td>Bicycle and pedestrian</td>
</tr>
<tr>
<td>Dongdan</td>
<td>3</td>
<td>At-grade 4-leg interchange</td>
<td>underpass at north-south direction; fly-over bridge at east-west direction</td>
<td>Bicycle and pedestrian</td>
</tr>
<tr>
<td>Dongsi Shi Tiao</td>
<td>11</td>
<td>Roundabout</td>
<td>Only the east has underpass</td>
<td>Bicycle</td>
</tr>
<tr>
<td>Jiang Zhai</td>
<td>6</td>
<td>At-grade 4 leg interchange</td>
<td>fly-over bridge at four directions</td>
<td>Bicycle</td>
</tr>
<tr>
<td>Chao Yang Park</td>
<td>2</td>
<td>At-grade T-intersection</td>
<td>underpass at west entrance</td>
<td>Bicycle and pedestrian</td>
</tr>
<tr>
<td>Da Wang</td>
<td>9</td>
<td>Under bridge</td>
<td>interchange bus stations and subway</td>
<td>Pedestrian</td>
</tr>
</tbody>
</table>

Table 1. General information of each selected junction
Locations of the chosen junctions are shown at fig. 3 below:

Figure 3. The locations of each junction

4.4 Identifying the problems and countermeasures

4.4.1 Main problems at the selected junctions:

- Lack of channelization for left turn bicycles which causes many conflicts between left turn bicycles and motor vehicles at intersections;
- Some pedestrians do not follow the rules when crossing the intersection;
- Some of the non-motorized vehicles drive on the motor vehicle lanes;
- No traffic signals for pedestrians at the large intersections, and no safety island for pedestrians to wait for second stage crossing;
- The traffic conflicts of right turn vehicles with pedestrians and non-motorized vehicles;
- Poor design of bus stations.
4.4.2 **The key countermeasures implemented at the selected junctions**

- Setting up a left turn waiting line allowing the left turn bicycles to cross the street in two stages;
- Setting the signal for right turn vehicles;
- Installing a leading sign and barrier to guide pedestrians using the existing facilities (such as: underpass or fly-over bridge);
- Installing refuge islands for pedestrian crossing;
- Modifying the length, location and radian of the barriers in the roundabout to separate the non-motorized vehicles from motor vehicles;
- Improving the bus station.

5. **Specific countermeasures taken at the selected junctions and the results**

5.1 **Set up the waiting line for left turn bicycles for two-step crossing**

**Problems:** Lack of channelization for left turn bicycles to across the junction, which caused many conflicts between left turn bicycles and motor vehicles.

**Objectives:** Increase the proportion of two-step crossing left turn bicycles, reduce the number of traffic conflicts and the risk of crashes, and reduce the speed of right turn vehicles.

**Example:** Xidan

**Outcome:** The pictures of before and after at Xidan are shown as below.

![Before](image1.png) ![After](image2.png)
By setting up the waiting line for left turn bicycles, the proportion of two-step left turn bicycles at the junction was greatly increased. Almost 80 percent of left turn bicyclists are now using the waiting line to finish their crossing. The bar chart below shows the comparison of before and after data.

Figure 4. Proportion of two step left turn bicycle

The chart below shows the total number of conflicts at the junction has declined from 22 to 16 after implementing the countermeasure. Among them, the number of serious conflicts has declined from 12 to 5, the proportion of serious conflicts also has declined from 55 percent to 31 percent (the data were from peak hours and taken by video).

Figure 5. Before and after comparison - conflicts
The mean speed and 85-percentile speed of right turn vehicles were also reduced after implementing the countermeasure. It is mainly because the volume of bicycles stopped at the waiting line made the space for right turn vehicles smaller and thus slows the vehicles down or even makes them stop. Consequently, it improves the VRU’s safety.

Table 2. Speed before and after comparison – Speed of right turn vehicles

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean speed</td>
<td>16.5 km/h</td>
<td>15.4 km/h</td>
</tr>
<tr>
<td>85% speed</td>
<td>22 km/h</td>
<td>20.7 km/h</td>
</tr>
</tbody>
</table>

Note: the speed is getting in the peak hours and sample size is 100 right turn vehicles.

5.2 Set signal for right turn vehicles

**Problems:** The volume of right turn vehicles is high, and vehicles turn right on red without giving way causes lots of conflicts with through bicycles and pedestrians.

**Objectives:** Reduce the conflicts between right turn vehicles and bicycles or pedestrians.

**Example:** Dawang

**Outcome:** The pictures of before and after at the junction are shown as below.

![Before](image1.png) ![After](image2.png)

Figure 6. Before and after pictures

After setting the signal for right turn vehicles, the total number of conflicts declined from 32 to 19, the number of serious conflicts declined from 14 to 7. The proportion of serious conflicts also
declined from 44 percent to 37 percent. Since there was no interruption of vehicles from west to east after setting the signal, the speed of right turn vehicles actually could increase (the conflicts were gotten by video in peak hours).

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
</tr>
</thead>
</table>

![Figure 7. Before and after comparison - conflicts](image)

By setting the signal for right turn vehicles, the conflicts between right turn vehicles and go through pedestrians can be effectively reduced, while the speed of right turn vehicles could be increased when traffic signal is green. The movement of bicycles has also increased as having free flow when right turn vehicle signal is red. Therefore, it is recommended to set the right turn vehicle signal in combination of bicycle through signal to separate the flows and move them in turns at the junctions where there is a separate lane for right turn vehicles.

5.3 Install leading signs and barrier to guide pedestrians using existing facilities

**Problems:** Pedestrians are requested to use either a fly-over bridge or underpass when crossing the street on the Changan street. However, without a traffic assistant in place, some people still across the street on the ground.

**Objectives:** Discipline pedestrians’ behaviour, guide pedestrians crossing the street to use the existing underpass or fly-over bridge, and reduce the risk of pedestrian crashes and conflicts.

**Example:** Xidan

**Outcome:** The pictures of **before and after** at Xidan are shown as below.
Installing leading signs and barrier to guide pedestrians to use the underpass changed pedestrians’ behaviour. The outcome of our post-intervention survey shows that the number of pedestrians crossing the junction on the ground declined from 27 to 12 per hour in peak hours, which resulted in reducing the risk of pedestrian crashes and conflicts with motor vehicles at the junction.

### 5.4 Install refuge islands for pedestrians

**Problems:** The junctions are too big for the pedestrians to cross in one stage.

**Objectives:** Provide pedestrians a safe space to wait for a second stage crossing, and reduce conflicts between the vehicles and pedestrians.

**Example:** Dongsi Shi Tiao

**Outcome:** Before and after pictures at Dongsi Shi Tiao are shown as below:
By installing the refuge island at the junction, 79 percent of the pedestrians feel much safer when crossing the street (the survey sample size was 200). The post-intervention survey shows that 89 percent of pedestrians use the refuge island to cross the junction in peak hours. The average walking speed of a person reduced from 1.3 m/sec to 0.9 m/sec. They felt more relaxed when crossing (data in peak hours).

5.5 Modify the length, locations and radian of the barriers at the roundabout

Problems: The barriers segregating bicycles from motor vehicles were set inappropriately; therefore, only few bicyclists used the lane setting for bicycles.

Objectives: Increase the compliance rate with traffic laws for bicyclists by getting them to use the bicycle lane to improve their safety on the road, and reduce the number of conflicts between bicycles and motor vehicles.

Example: Dongsi Shi Tiao (roundabout)

The picture below shows the roundabout is divided into 6 sections.
Specific Countermeasures:

- make the bicycle lane one meter wider at the section 1
- change the guiding line at entrances from an arc shape into a straight line at the section 1 and 3
- a nine-meter barrier has been installed to segregate the bicycles and motor vehicles between the sections 1 and 6.

Outcome: By taking the above countermeasures, the compliance rate of bicyclists has been increased at most of the sections (data in peak hours).
5.6 Improve the situation of bus station

Problems:

a) The bus stop at the north exit was located very closely to the junction, and many buses stopped there.

b) There was a high volume of passengers either waiting there for the other bus or crossing to
transfer to the subway.

**Objectives:** Reduce the conflicts between alighting passengers and bicyclists, and guide passengers using the zebra crossing line on the road.

**Example:** Da Wang

**Specific Countermeasures:**

- Build a 60 meters long platform to reduce the conflicts between alighting passengers and bicyclists
- Set the median barriers to guide people using zebra crossing line when crossing the junction;
- Paint a zebra crossing line between the bus stop and sidewalk

**Outcome:** Before and after pictures at the junction are shown as below.

![Before and after pictures](image)

Figure 14. Before and after pictures – moving the location of the bus stop
By setting the median barriers, 95 percent of passengers are crossing the street via the zebra compared with the previous 35 percent. After setting the zebra crossing line between the bus stop and sidewalk, 43 percent of passengers use the zebra crossing when they get off the bus.

6. Discussion and Conclusions

Through the before and after analysis of the countermeasures, it can be clearly seen that the safety of VRU has been improved at the selected six junctions in Beijing. However, it is worth mentioning that the countermeasures used in the project are neither expensive nor unique – they are routine work for the local traffic police. What makes the project unique are:

a) Multi-sector cooperation. The project involved the appropriate government agencies, an academic institution and an international road safety agency. The local partners played a crucial role to the success of the project and merits of each party were fully used in the project.

b) The project was carried out in a systematic and scientific manner. Evidence based decision making and the before/after data comparison are the highlights of the project. It has proven that low cost engineering countermeasures can effectively improve road safety for VRUs.

However, what have been implemented at each selected intersections are only the beginning of the long process, there still are a lots of room for continuous improvement. With more implementation the team believes experience will show even more reductions in the risk factors being evaluated.

As an output of the project, the local project team developed a good practice manual - Design & Operational Guide on Vulnerable Road User Safety at Junctions based on international and national good practice in VRU safety and experience gained from the project. The manual aims to provide a
design and operational guide for reducing conflicts and improving the safety situation of VRUs at urban junctions, whilst taking account of traffic efficiency. It introduces the relevant road and facilities design, as well as management countermeasures. The manual will be published in both Chinese and English. We hope it will be used as a reference book by leaders and professionals in road safety related government agencies, road design and traffic engineering institutions, traffic management divisions, and relevant research institutes and universities.

REFERENCE

1. World Report on Road Traffic and Injury Prevention 2004
2. Li Wei The pedestrian and bicyclist plan and practice, 2008
ABSTRACT
Determining the various components of road travel that represent elevated levels of risk would be a fundamental step in the identification of risk issues on our roads. Once identified, the occurrence of these road safety issues can be targeted for improvements, thus making progress towards the safety on our roads. To that end, we have developed a risk analysis model and have determined some road safety issues of high-risk. The model weighs incident data from the National Collision Data Base (NCDB) against exposure data from the Canadian Vehicle Survey (CVS). Fatality rates and relative risk levels were computed for all groupings of data common to both datasets.

Without the exposure data (CVS), it would only be possible to compute casualty rates by population, number of licensed drivers, or the number of registered vehicles. This is limited; it does not allow one to compare risk factors at micro levels; for example, the risk of nighttime driving versus daytime driving. The exposure data enables the calculation of standardized risk values based on the actual amount of kilometers driven during the respective times, and allows for the comparison of the different risk factors to one another.

There are two ways of calculating risk; casualty rates and relative risk. Casualty rates take the number of road incidents that occurred under certain conditions divided by the number of kilometers driven under the same travel conditions. One could calculate similar rates based on different conditions in order to make comparisons. The relative risk is simply the proportion of collisions with a certain characteristic versus the proportion of road travel with the same characteristic. It has no units, and if the risk is greater than 1, it means that the collisions with the characteristic under study are over-represented relative to the kilometers driven having the same characteristic. For example, a relative risk of 2 means that the proportion of incidents with the characteristic under study is twice the corresponding proportion of kilometers driven. As one can imagine, this allows us to extend our analysis to implemented programs, such as graduated licensing programs, in order to determine their effectiveness on reducing risk on our roads.
1 INTRODUCTION
Casualty rates by population, by number of licensed drivers, or by the number of registered vehicles have traditionally been used as road safety risk measures. However, casualty rates do not allow for the comparison of risk factors at micro levels. The availability of travel activity data, such as the Canadian Vehicle Survey (CVS), makes these comparisons possible.

Traditional casualty rates can be misleading, as they do not take into account the amount of driving done. For example, comparing children versus adults might yield casualty rates that are higher for adults than for children, but children probably travel much less than adults.

The exposure data in terms of vehicle-kilometers travelled and passenger-kilometers travelled estimated in the CVS is key in objectively determining elements that are of high risk on our roads.

2 METHODOLOGY
2.1 Risk measures
The methodology has been documented at Ref.1 and Ref.2. But, it shall be repeated here for the convenience of our readers. There are two ways of calculating risk; casualty rates and relative risk.

Casualty rates are computed as:
\[
R^F (I | TG_i, TC_j, T_z) = \frac{(I | TG_i, TC_j, T_z)}{(E | TG_i, TC_j, T_z)} \tag{1}
\]

Where:
I \rightarrow Indicate the type of road incident (injury, fatality, etc.)
TCj \rightarrow The travel conditions
Tz \rightarrow Time period
TGi \rightarrow Target group of entities
(I | TG_i, TC_j, T_z) \rightarrow Is the frequency (count) of incidents.
(E | TG_i, TC_j, T_z) \rightarrow Is the number of kilometers driven.

And relative risk is computed as:
\[
R^P (I | TG_i, TC_j, T_z) = \frac{p(I | TG_i, TC_j, T_z)}{p(E | TG_i, TC_j, T_z)} \tag{2}
\]

Where:
p(I | TG_i, TC_j, T_z) \rightarrow The corresponding proportion of incidents.
p(E | TG_i, TC_j, T_z) \rightarrow The corresponding proportion of KMs.

The relative risk is simply the proportion of collisions with a certain characteristic versus the proportion of road travel with the same characteristic. It has no units, and if the risk is greater than 1, it means that the collisions with the characteristic under study are over-represented relative to the kilometers driven having the same characteristic. For example, a relative risk of 2
means that the proportion of incidents with the characteristic under study is twice the corresponding proportion of kilometers driven.

The relative risk is a measure based strictly on equity rather than efficiency. For example, an issue might have a very high relative risk, but a very low average number of fatalities. Therefore, addressing such an issue will reduce the number of fatalities by only a small number. One would therefore prioritize issues that have a high relative risk value as well as a large number of associated fatalities.

2.2 Databases
The incident data was obtained from the National Collision Data Base (NCDB). NCDB is a collection of data pertaining to traffic collisions occurring in the ten provinces and the three territories. These collisions are all those deemed reportable, i.e. they occur on public roads and they incur bodily harm and/or property damage exceeding a stipulated dollar threshold. (Ref.3)

The exposure data comes from the Canadian Vehicle Survey. The tabulations provided in the Statistics Canada reports (Ref.4) are insufficient to calculate the risk as reported in this study. The tabulated data does not include 2-way tables, or the groupings of interest. Therefore, the micro data itself was used to compute the corresponding vehicle-kilometers and passenger-kilometers driven.

One should also observe that, while NCDB contains collision data from the territories, CVS only has macro data for the territories, therefore the territories had to be excluded from this analysis.

2.3 Overview of the risk analysis model
Risk can be computed for different injury levels: fatalities, serious injuries, all injuries, and all collisions. The exposure measure can be vehicle-kilometres or passenger-kilometres. The variables that are common to both databases (CVS and NCDB) are: jurisdiction (only provinces), vehicle type (heavy trucks/automobiles/light trucks and vans), vehicle age, day of the week, time of day, age of driver, sex of driver and passenger age1 (under 5, 5-14, over 14).

Fatality is the most reliable injury level (Ref.9); as well, interventions aimed at reducing fatalities will likely also reduce injuries of all severities. As such, this paper focuses solely on fatalities. Fatality rates as well as relative risk of fatalities, for both vehicle-kilometres and passenger-kilometres, for the years 2001 to 2006 (overall) are reported. All one-way and two-way tables were computed for each combination of the variables above.

1 This variable will not be examined in this paper as the passenger age groupings available are not sufficiently detailed.
3 HIGH-RISK FACTORS

To determine the high-risk factors, all of the fatality tables for single variables were examined, then all cases where the relative risk (using either vehicle KMs or passenger KMs) of fatalities was greater than 1.5 were isolated. The results are shown at Table 1.

Table 1: High-Risk factors for fatalities.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Average number of fatalities per year</th>
<th>Average fatality rate per billion vehicle-kilometres ((10^{-9}))</th>
<th>Average fatality rate per billion passenger-kilometres ((10^{-9}))</th>
<th>Relative risk (vehicle-kilometres)</th>
<th>Relative risk (passenger-kilometres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Age</td>
<td>Under 20</td>
<td>182</td>
<td>61.8</td>
<td>35.9</td>
<td>5.62</td>
<td>5.40</td>
</tr>
<tr>
<td></td>
<td>20-24</td>
<td>236</td>
<td>30.7</td>
<td>21.0</td>
<td>2.79</td>
<td>3.15</td>
</tr>
<tr>
<td></td>
<td>75-84</td>
<td>99</td>
<td>30.7</td>
<td>17.8</td>
<td>2.79</td>
<td>2.67</td>
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<tr>
<td></td>
<td>85+</td>
<td>25</td>
<td>79.4</td>
<td>46.8</td>
<td>7.22</td>
<td>7.03</td>
</tr>
<tr>
<td>Time of Day</td>
<td>00:00-02:59</td>
<td>294</td>
<td>60.5</td>
<td>40.0</td>
<td>6.73</td>
<td>7.33</td>
</tr>
<tr>
<td></td>
<td>03:00-05:59</td>
<td>210</td>
<td>41.3</td>
<td>30.7</td>
<td>4.60</td>
<td>5.62</td>
</tr>
<tr>
<td></td>
<td>21:00-23:59</td>
<td>367</td>
<td>22.6</td>
<td>12.8</td>
<td>2.52</td>
<td>2.33</td>
</tr>
<tr>
<td>Vehicle age</td>
<td>12 to 14</td>
<td>361</td>
<td>13.6</td>
<td>8.5</td>
<td>1.52</td>
<td>1.56</td>
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<tr>
<td></td>
<td>15+</td>
<td>363</td>
<td>18.4</td>
<td>11.9</td>
<td>2.05</td>
<td>2.17</td>
</tr>
<tr>
<td>Jurisdiction</td>
<td>P.E.I.</td>
<td>14</td>
<td>21.1</td>
<td>12.8</td>
<td>1.95</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Drivers under 20, drivers over 85, and driving between the hours of 00:00-02:59 and 03:00-05:59, are the highest elements of risk. Older vehicles experience a higher level of risk than newer vehicles.

The fatality rate by passenger-kilometres is always smaller than the fatality rate by vehicle-kilometres as it is calculated from the same number of fatalities divided by a larger number (i.e. passenger-kilometres).
4 ELEMENTS OF HIGH-RISK INVOLVING TWO VARIABLES

Next, all two-way tables were examined to isolate all the cases with at least an average of 5 fatalities per year and a relative risk exceeding 2.5 (the cut-off values were chosen quite arbitrarily by convenience). Table 2 presents high-risk combinations involving driver age, and Table 3 presents those high-risk combinations that involve time of day but not driver age.

Table 2: Elements of high risk for fatalities involving driver age.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Level</th>
<th>Driver Age</th>
<th>Average number of fatalities per year</th>
<th>Average fatality rate per billion vehicle-kilometers ((10^{-9}))</th>
<th>Average fatality rate per billion passenger-kilometers ((10^{-9}))</th>
<th>Relative risk (vehicle-kilometers)</th>
<th>Relative risk (passenger-kilometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Day</td>
<td>00:00-02:59</td>
<td>Under 20</td>
<td>27</td>
<td>179.4</td>
<td>96.5</td>
<td>32.94</td>
<td>29.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-24</td>
<td>38</td>
<td>141.9</td>
<td>89.4</td>
<td>26.05</td>
<td>26.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85+</td>
<td>6</td>
<td>754.2</td>
<td>536.7</td>
<td>3.96</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td>03:00-05:59</td>
<td>Under 20</td>
<td>17</td>
<td>427.9</td>
<td>353.9</td>
<td>78.56</td>
<td>106.80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-24</td>
<td>33</td>
<td>221.4</td>
<td>149.1</td>
<td>40.64</td>
<td>45.00</td>
</tr>
<tr>
<td></td>
<td>21:00-23:59</td>
<td>Under 20</td>
<td>27</td>
<td>37.6</td>
<td>21.0</td>
<td>6.91</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-24</td>
<td>33</td>
<td>29.3</td>
<td>18.9</td>
<td>5.39</td>
<td>5.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75-84</td>
<td>6</td>
<td>25.4</td>
<td>13.9</td>
<td>4.67</td>
<td>4.20</td>
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<tr>
<td>Vehicle Age</td>
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<td>33</td>
<td>40.4</td>
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<td>7.43</td>
<td>7.53</td>
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<tr>
<td></td>
<td></td>
<td>20-24</td>
<td>34</td>
<td>24.3</td>
<td>16.2</td>
<td>4.46</td>
<td>4.88</td>
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<tr>
<td></td>
<td></td>
<td>75-84</td>
<td>14</td>
<td>18.1</td>
<td>11.2</td>
<td>3.33</td>
<td>3.37</td>
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<td></td>
<td>Vehicle 15+</td>
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<td>34.3</td>
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<td>10.36</td>
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<tr>
<td></td>
<td></td>
<td>20-24</td>
<td>31</td>
<td>47.0</td>
<td>32.7</td>
<td>8.63</td>
<td>9.88</td>
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<td>14</td>
<td>260.8</td>
<td>124.2</td>
<td>3.76</td>
<td>3.75</td>
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<td></td>
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<td>85+</td>
<td>6</td>
<td>71.3</td>
<td>35.3</td>
<td>13.11</td>
<td>10.65</td>
</tr>
</tbody>
</table>
Young drivers at night-time represent the highest levels of risk (both the under 20 and the 20 to 24 age groupings). This illustrates the necessity of curfews within graduated licensing programs. It also indicates that the exit of graduated licensing program after two years of driving with a clean driving record may not be sufficient.

Older vehicles and young drivers also constitute a poor combination. It is to be observed that for drivers under 25, the risk increases with the age of the vehicle. For young drivers, the risk is the highest on days surrounding the weekend. The risk is lower for light trucks and vans (LTV) than it is for passenger cars for drivers of any age, which can probably be attributed to the protective effect of LTV over that of passenger cars (or the vulnerability of passengers cars relative to LTV and heavy trucks), as discussed by Toy and Hammit (Ref.7) and Fredette et al. (Ref.10).
Table 3: Elements of high risk for fatalities involving time of day but not driver age.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Second Variable</th>
<th>Average number of fatalities per year</th>
<th>Average fatality rate per billion vehicle-kilometers (10^7)</th>
<th>Average fatality rate per billion passenger-kilometers (10^9)</th>
<th>Relative risk (vehicle-kilometers)</th>
<th>Relative risk (passenger-kilometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00-02:59</td>
<td>Alberta</td>
<td>22</td>
<td>57.4</td>
<td>35.2</td>
<td>5.22</td>
<td>5.29</td>
</tr>
<tr>
<td></td>
<td>B.C.</td>
<td>31</td>
<td>113.7</td>
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<td>13.75</td>
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<tr>
<td></td>
<td>Manitoba</td>
<td>7</td>
<td>54.5</td>
<td>36.7</td>
<td>4.95</td>
<td>5.51</td>
</tr>
<tr>
<td></td>
<td>New Brunswick</td>
<td>7</td>
<td>198.3</td>
<td>106.9</td>
<td>18.03</td>
<td>16.07</td>
</tr>
<tr>
<td></td>
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<td>48.4</td>
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<td>5.22</td>
</tr>
<tr>
<td></td>
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<td>60.3</td>
<td>42.8</td>
<td>5.48</td>
<td>6.44</td>
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<td></td>
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<td>9</td>
<td>120.9</td>
<td>72.7</td>
<td>10.99</td>
<td>10.93</td>
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<tr>
<td>03:00-05:59</td>
<td>Alberta</td>
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<td>43.5</td>
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<td>3.95</td>
<td>5.15</td>
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<td>B.C.</td>
<td>23</td>
<td>130.8</td>
<td>85.3</td>
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<td>12.82</td>
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<td>Manitoba</td>
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<td>43.7</td>
<td>37.3</td>
<td>3.97</td>
<td>5.60</td>
</tr>
<tr>
<td></td>
<td>Ontario</td>
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<td>28.5</td>
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<td>4.29</td>
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<td>86.2</td>
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<td>23.1</td>
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<td>3.48</td>
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<td>15.5</td>
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<td>6.14</td>
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<td>11.06</td>
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<tr>
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<td>23</td>
<td>27.7</td>
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<td>5.09</td>
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<td></td>
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<td>58.5</td>
<td>16.34</td>
<td>17.67</td>
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<tr>
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<td>7.2</td>
<td>2.57</td>
<td>2.17</td>
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<tr>
<td>00:00-02:59</td>
<td>Vehicle Age 12 to 14</td>
<td>45</td>
<td>156.4</td>
<td>103.7</td>
<td>17.40</td>
<td>18.96</td>
</tr>
<tr>
<td></td>
<td>Vehicle Age 15+</td>
<td>41</td>
<td>153.8</td>
<td>92.4</td>
<td>17.12</td>
<td>16.90</td>
</tr>
<tr>
<td>03:00-05:59</td>
<td>Vehicle Age 12 to 14</td>
<td>32</td>
<td>67.2</td>
<td>53.3</td>
<td>7.48</td>
<td>9.75</td>
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<tr>
<td></td>
<td>Vehicle Age 15+</td>
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<td>52.6</td>
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<td>9.62</td>
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<tr>
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<td>Vehicle Age 12 to 14</td>
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<td>19.1</td>
<td>3.68</td>
<td>3.49</td>
</tr>
<tr>
<td></td>
<td>Vehicle Age 15+</td>
<td>50</td>
<td>54.5</td>
<td>30.9</td>
<td>6.06</td>
<td>5.65</td>
</tr>
<tr>
<td>00:00-02:59</td>
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<td>70</td>
<td>45.2</td>
<td>27.3</td>
<td>5.03</td>
<td>4.99</td>
</tr>
<tr>
<td></td>
<td>Passenger Vehicle</td>
<td>186</td>
<td>74.4</td>
<td>50.4</td>
<td>8.28</td>
<td>9.23</td>
</tr>
<tr>
<td>03:00-05:59</td>
<td>LTV</td>
<td>52</td>
<td>28.7</td>
<td>20.6</td>
<td>3.19</td>
<td>3.78</td>
</tr>
<tr>
<td></td>
<td>Passenger Vehicle</td>
<td>135</td>
<td>66.9</td>
<td>49.7</td>
<td>7.44</td>
<td>9.09</td>
</tr>
</tbody>
</table>
While several provinces have high-risk at night, Ontario, Nova Scotia and Alberta have the lowest risk levels overall, especially when dealing with passenger kilometres. These provinces have had graduated licensing programs that include a night-time curfew since 1994 (for Ontario and Nova Scotia) and 1999 (for Alberta). This data confirms that curfews reduce the levels of risk.

Saturday and Sunday between the hours of 00-06 am (i.e. Friday night and Saturday night) and to some extent Friday between 00-06 am (Thursday night) have the highest risk among all time periods. Vehicles of all ages (except 3-5) have a high risk at night, but the risk increases with vehicle age.

5 GRADUATED LICENSING PROGRAMS
The risk analysis methodology can be applied to evaluating graduated licensing (GL). Instead of comparing graduated licensing within each province in a before and after manner; the provinces that implemented their graduated licensing program prior to 1998 can be compared to provinces that have implemented their GL program in or after 1998 and to those that do not have a night curfew within their GL program or did not have a GL program that would have been implemented in time to cover the full range of drivers under 20.

It is important to note that the provinces that have implemented graduated licensing after 1998, were as of 2001, still in transition. For example, if the GL program was implemented in 2000; in year 2001, most of the 17-19 years old would have obtained their licenses prior to the graduated licensing system.

Table 4: Risk of fatalities associated with drivers under 20 per graduated licensing system.

<table>
<thead>
<tr>
<th>From 2001 to 2006</th>
<th>Average number of fatalities per year</th>
<th>Fatality rate per billion vehicle-kilometers ((10^{-9}))</th>
<th>Fatality rate per billion passenger-kilometers ((10^{-9}))</th>
<th>2001-2006 Relative risk (vehicle-kilometers)</th>
<th>2001-2006 Relative risk (passenger-kilometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL before 1998</td>
<td>54</td>
<td>45.8</td>
<td>25.0</td>
<td>4.20</td>
<td>3.80</td>
</tr>
<tr>
<td>GL after 1998</td>
<td>48</td>
<td>53.5</td>
<td>32.1</td>
<td>5.02</td>
<td>4.90</td>
</tr>
<tr>
<td>No curfew/ No GL</td>
<td>79</td>
<td>90.7</td>
<td>55.8</td>
<td>8.44</td>
<td>8.65</td>
</tr>
</tbody>
</table>

Graduated licensing programs (with curfew) have lower fatality rates and relative risk of fatality for drivers under 20 years old than provinces without graduated licensing or provinces that have graduated licensing programs without curfews. Graduated licensing programs with curfews reduce the risk by approximately 50% for drivers under 20 years old.
CONCLUSION
The largest risk was that of young drivers (under 25) at night-time. Evidence shows that graduated licensing programs with a curfew between midnight and 6 am are more effective at lowering risk than those without these characteristics.

Driving Friday and Saturday nights after midnight (more specifically, Saturday and Sunday mornings) also introduces high levels of risk, especially for drivers under 25 or vehicles over 15 years old. The combination of the 3 (weekend after midnight, drivers under 25, and older vehicles) is of significant concern. Older drivers (75 and over) also experience high levels of risk due to their fragile nature (Ref.11).

The availability of comparable incident and exposure data is clearly crucial in determining various levels of risk found on our roads. Our Risk Analysis model helps determine key areas of concern, and has the potential to extend even further.

The need for improved collision and exposure data cannot be stressed enough. There are intuitive areas of concern that have yet to be captured in the scope of any database. With improved data collection will come significant findings that lead to potential countermeasures aimed at reducing risk on our roads. Having the data to back up the intuition is often underrated.
REFERENCES


BRINGING STRUCTURE INTO ROAD SAFETY EVALUATION: A HIERARCHY OF INDICATORS

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ABSTRACT
In recent years, there has been an explosion of interest in indicators in several domains. This reflects growing recognition of the important role indicators can play as a tool for enhancing the quality of decision making. Indicators express an aspect of a phenomenon in an understandable and relevant way and are useful in terms of monitoring, evaluation and communication. Like other policies, road safety policy could benefit from the use of indicators able to measure changes and progress towards postulated targets. Currently, the number of road fatalities or injury accidents per million inhabitants are often used indicators. Nevertheless, many more relevant road safety indicators exist. In order to increase the level of road safety, as many factors as possible influencing the frequency and severity of accidents should be considered. For example, key road safety risk factors (such as alcohol and drugs, speed, protective systems, vehicles, etc) should be represented by appropriate indicators as well.

To keep an overview on the structure and interrelationships between all indicators a framework should be elaborated on. This paper aims at presenting a hierarchical road safety indicator framework that provides a clear structure in the set of road safety indicators and is an interesting starting point for indicator (and index) analysis. In the first layer, general categories of road safety indicators are distinguished such as outcome indicators, risk indicators, etc. Next, each category (e.g. risk) is divided into different aspects (e.g., speeding). At the subsequent level of the hierarchy, various specific (e.g. speed) indicators are formulated (e.g., the average speed per road type; the share of drivers violating the legal speed limit; etc). By making use of a layered hierarchy the structure within the extensive set of road safety indicators can be overseen.

Furthermore, the combination of various indicators into an aggregated index has advantages in terms of communication and benchmarking. The hierarchy of indicators enables a stepwise combination in which first the most specific (e.g. speed) indicators are combined in a (speed) index. Together with other (e.g. alcohol and drugs) indexes an overall risk index can be composed, which can be grouped with other indexes (e.g. the outcome index) in the end. That way, it is possible to evaluate the road safety performance of countries on the overall road safety index level, the risk index level, the speed index level or the level of an individual indicator (depending on the context).

1 INTRODUCTION
Road safety is an important topic as the price paid for mobility is too high. Every day around the world, more than 3,000 people die from road traffic injury (World Health Organization, 2004). In the European Union, every year more than 40,000 persons are killed and more than 1.7 million
injured (European Commission, 2006). Although the number of road fatalities in Europe dropped significantly at the beginning of the 1990s, the trend has been less marked in recent years. In the battle for road safety, the European Union has set itself the ambitious goal to reduce the number of people killed in traffic between 2000 and 2010 by half (European Commission, 2001). In addition, challenging road safety targets have been set on national levels (see e.g., European Road Safety Observatory, 2006; Organisation for Economic Co-operation and Development and European Conference of Ministers of Transport, 2006). However, in order to meet these challenging targets insight in the road safety issue is required. In other words, information on the incidence and types of accidents as well as a detailed understanding of the circumstances that lead to accidents is necessary to guide safety policy (World Health Organization, 2004). The use of indicators – for quantifying the complex phenomenon of road safety – is valuable in this respect. Therefore, the concept and purpose of indicators is explained first, followed by the introduction of a hierarchical framework for bringing structure into the set of indicators (Section 2). In Section 3, another topic with regard to an extensive set of indicators is handled, i.e., the combination of indicators into an index. In particular, the idea behind this summary of information is explained as well as the theoretical aspects that need to be considered. This paper concludes with some conclusions (Section 4).

In recent years, there has been an explosion of interest in indicators in several domains such as environment (e.g., Hens et al., 2005), economy (e.g., Kaminsky et al., 1998) and innovation (e.g., Kleinknecht et al., 2002). Indicators can be described as measures that summarize an aspect of a phenomenon in an understandable and relevant way. They express scientific knowledge in a form that supports decision makers to take better informed and more appropriate choices. From literature (Al Haji, 2005; Hens et al., 2005; Litman, 2005; Nardo et al., 2005; Organisation for Economic Co-operation and Development, 2001; Salzman, 2003; Van Reeth and Vanongeval, 2005) it appears that indicators can be used in a number of ways, such as:

- measuring relative performance/benchmarking: indicators are measures derived from a series of observed facts that can reveal relative positions in a given area. Best-in-class and superior performance can be established.
- drawing attention to particular issues: indicators are suited for communication purposes, such as informing policymakers or activating and stimulating the public alertness.
- identifying trends: in case an indicator is measured at regular intervals, the directions of change over time and across different subjects can be pointed out.
- predicting problems: indicators can serve as warning signal for policymakers and are important guidelines for governments and authorities.
- assessing the impact of policy measures: indicators can be used for evaluating intended output and policy effects, enabling to judge several options.
- setting targets and priorities: based on former indicator values and values from other subjects, targets can be set. A comparison between different indicators may reveal which aspects need (more) urgent action.
- evaluating progress towards targets: in case of indicator measurements at regular moments in time the progress towards stated targets can be monitored closely and the achievement estimated. At certain time points, re-evaluation of goals or remedial action might be appropriate.
presenting in a comprehensible way: indicators can present a large amount of information in a clear way. They are means for visualising the current situation. That way, problems become more concrete and subject to discussion.

The idea of using indicators for the continuous monitoring and analysis of processes exists for decades. Modern use of performance measures rose out of the Deming total quality management movements of the 1950s in Japan. The principles rely on developing goals that can be related to measurable results, monitoring those results and assessing strategies to improve performance (National Cooperative Highway Research Program, 2003).

2 HIERARCHICAL FRAMEWORK

In this section, indicator frameworks or conceptual models for structuring road safety indicators (and their interrelationships) are described. In literature (see e.g., Environment Canada et al., 1999; Maclaren et al., 1995; Segnestam, 2002) several types of indicator frameworks can be found. Each framework organizes the information in a unique way. For example, in a goal-based framework indicators are organized according to how they correspond to various goals; a causal-based framework structures indicators into categories of pressure, state and response (or an extension hereof).

Road safety being a complex matter that is affected by many factors in various ways, this research will present road safety indicators in a conceptual framework. More specifically, a hierarchical framework is developed consisting of several layers. The first layer is composed of general categories of road safety indicators. Based on literature (see e.g. Wegman et al., 2008), four general categories are identified. Outcome indicators refer to the situation after an accident happened and injuries occurred. Nowadays, the road safety situation in a country is often described and compared to that in other countries using the number of fatalities (for example per million inhabitants). Apart from these outcome indicators, risk indicators provide useful information. They quantify the main aspects leading to the occurrence of accidents and casualties. The European Transport Safety Council (2001) advised to develop indicators with respect to behavior (such as speeding), vehicles, infrastructure and trauma management. Thirdly, the initiatives taken by policymakers aimed to improve the level of road safety can be expressed by means of policy indicators. By studying these indicators, the efforts (e.g., the number of hours of police patrol regarding drunk driving) can be quantified and subsequently linked to the effects (i.e., the share of persons driving while being under the influence of alcohol). Finally, a set of background indicators (e.g., the age distribution of the population) is considered. Although they have a less direct link with the road safety outcome level, they should be taken into account when drawing conclusions concerning road safety.

Next, each of the four categories can be further elaborated in the second layer. In order to obtain a well-structured road safety indicator set in the end, each category is divided into subcategories. The outcome category may consist of injury accidents, fatalities, casualties, etc. The risk category is captured by some human, vehicle and environmental factors (see e.g., Sabey and Taylor, 1980). With respect to policy, a division into engineering, enforcement and education (referred to as the 3 E’s) is often made. And finally, the background category is concretized by demographic, economic, geographic and transport factors.

In the third layer, each subcategory is further specified. Here, this is illustrated for the human-vehicle-environment risk factors. The hierarchical framework visually presented in Figure 1 shows this third layer for these subcategories only. However, the idea is the same for the other subcategories. The third layer breaks the human category down into road safety risk factors.
related to the human behavior, such as alcohol, speed, protective systems, etc. The vehicle factor can refer to several aspects, for example cargo, visibility and technical aspects. The environmental factor captures the infrastructure on the one hand and trauma management on the other.

Since the third layer still consists of generally broad subcategories for which road safety indicators need to be developed, a fourth layer can be presented. The factor speed for example can be divided into average speed, variability in speed and speed offences. With respect to protective systems, seatbelts (in the front and back seats) can be separated from helmets and child’s seats. A last example concerns the trauma management factor for which the process of medical assistance can be expressed at the accident scene, during the transportation and during the stay in the hospital.

Figure 1: Hierarchical framework for road safety indicators

Different layers in the hierarchy have been presented. By concretizing each aspect in a subsequent layer based on existing theory and literature, a more extensive and well-balanced framework is obtained. Each of the factors in the final layer need to be expressed by appropriate indicators. The selection of indicators is outside the scope of this paper which focuses on the concept of a hierarchical framework for structuring indicators. Nevertheless, the evaluation of possible road safety indicators based on a set of selection criteria – such as relevance, measurability, data reliability, etc – has been discussed in earlier research (see Hermans, 2009). In addition, several sources listing road safety indicators can be found nowadays. In order to obtain an enriched indicator set for drawing road safety enhancing conclusions, indicators referring to each aspect in the above framework should be considered.

3 COMBINATION OF INDICATORS

Each indicator (whether it concerns the number of casualties, the average speed, the cargo, the quality of the trauma care in the hospital or the transport situation in a country) can be studied separately. Indicator data can be collected, either for one particular country over time or for a
number of countries at one (or more) moment(s) in time. However, the simultaneous considering of several indicators can offer new insight. Given the high number of relevant road safety risk aspects (of which some are listed in Figure 1), the combination of indicators in a so-called index is valuable. One of the main advantages of an index is that a more overall picture is presented as a multitude of information is captured in this index. Moreover, the combination of indicators results in one index score, enabling easy comparison across countries. Wegman et al. (2008) state that an index is characterized by the words ‘simplification’, ‘quantification’ and ‘communication’.

The final aim is to create a road safety index which captures all relevant (outcome, risk, policy and background) road safety aspects. Based on an extensive set of indicator values and an appropriate combination methodology, a road safety index score can be computed for each country. This score can then be used for ranking countries based on their index score and is therefore an effective communication tool. Moreover, it can be used for benchmarking as the relative road safety performance of each country can be assessed and the best-in-class country can be revealed. Finally, this index enables monitoring the evolution over time and making predictions.

Limited research has been performed regarding the combination of road safety indicators. However, the creation of indexes in other domains offers valuable insights. During the last decade, indexes have been developed in various domains. Some well-known examples are the human development index (by the United Nations), the environmental sustainability index (by the World Economic Forum) and the growth competitiveness index (by Harvard University) (Saisana and Tarantole, 2002).

In general, two basic approaches are available for aggregating indicators (Sharpe, 2004). The first one is the monetary approach in which variables are expressed in monetary terms first and then simply added (the gross domestic product is an example hereof). The second approach is the composite indicator approach in which domains represented by a set of indicators are combined using weights. This second approach is described in the handbook on constructing composite indicators (Nardo et al., 2005). Different methods for assigning weights to indicators have been used in practice (see e.g. the internal market index 2004 (Tarantola et al., 2004), the environmental sustainability index (Yale Center for Environmental Law and Policy and Center for International Earth Science Information Network, 2005) and the meta-index of sustainable development (Cherchye and Kuosmanen, 2004)).

However, applications of the index methodology on a hierarchy of indicators are rare. It is nevertheless essential to take the hierarchical structure of indicators into account. In the next paragraphs, the main steps to take in creating an index are discussed. Next, the methodological process behind the combination of a hierarchy of indicators is discussed.

Eight steps need to be taken in the creation of an index (Hermans, 2009):

1. **Selecting indicators**: this first step decides on which indicators to combine in an index.

2. **Collecting indicator data**: data need to be found for the indicators deduced in the previous step. Ideally, time series data for a large set of countries are easily accessible in reliable databases.

3. **Univariate analysis**: based on the collected indicator values, each indicator is studied separately. By means of visualisation and basic summary statistics, an idea about the distribution of the indicator values can be obtained. Extreme values might need a closer look as they could become unintended benchmarks. Next, all data should be made comparable. This process is called normalisation. As the indicators might differ in magnitude, be expressed in different units or expose great variation with respect to the...
mean, they may cause bias in the index. Often used methods for normalisation are standardisation, rescaling and rank numbers. Thirdly, the imputation of missing values in the data set is dealt with at this stage. Several possible methods can be considered in this respect, like mean substitution, regression imputation, expectation-maximisation imputation or multiple imputation (Nardo et al., 2005).

4. **Multivariate analysis:** this step provides insight into the structure and interrelationships of the data set by studying the indicators simultaneously. The appropriateness of the indicator set for combination in an index is assessed by means of correlation analysis, internal consistency analysis, principal components analysis, cluster analysis and regression analysis.

5. **Weighting:** a weight should be assigned to each indicator. The set of weights has a large impact on the index scores. In literature, several weighting methods can be found, none of them being a priori the best technique. Weights based on statistical methods (such as factor analysis), participatory methods (e.g., budget allocation), optimization methods (like data envelopment analysis) and equal weighting are the most common techniques. Relevant methods for the problem under study should be evaluated.

6. **Aggregation:** the mathematical formula for combining the indicators needs to be selected. In this respect, it is important to decide how the index consists of its indicators and to which extent compensation between good and bad indicator scores is allowed.

7. **Robustness testing:** it is important to rigorously test the robustness of the index to the assumptions and methodological choices made. The uncertainty in the final result with respect to the indicators included, the imputed missing values, the normalisation technique chosen, the selected weighting method and the applied aggregation operator can be quantified. Moreover, it can be indicated which of these factors imply the largest uncertainty and should therefore be decided upon.

8. **Computing, evaluating and visualising the index scores:** using the (imputed) normalised indicator data, the weights and the aggregation operator, a final index score can be calculated for each country. The relationship between the composite road safety index and other related indicators or indexes (such as the corruption perceptions index; Lambsdorff, 2004) will be assessed. Finally, the results should be visualised in a clear way. In addition to a ranking, various types of graphs can be produced.

In case of a hierarchy of indicators, the eight steps in the methodological process for combining indicators need to be applied more than once. This is shown in Figure 2. First, the methodology is used to combine the indicators of the final (fourth) layer. In other words, the average speed indicator, the variation in speed indicator and the speed offences indicator are combined in a so-called speed index. The same applies to the other factors in the fourth layer (such as alcohol, protective systems, etc). Next, these constructed indexes are combined in a so-called human index. Each country will obtain a score on this human index which represents its relative performance with respect to alcohol, speed, protective systems, ... behavior. Subsequently, a risk index score can be obtained by applying the methodology to the human index, the vehicle index and the environment index. In the end, one overall road safety score can be computed in which the outcome index, the risk index, the policy index and the background index are represented.
Depending on the context, the road safety situation in a country can be evaluated at an overall or a more detailed level. The overall road safety index score can be computed – which captures a multitude of diverse indicators – and subdivided into an outcome performance, a risk performance, a policy performance and a background performance. At the same time, a human index, a vehicle index and an environment index score are provided. This enables a country to have an idea on its strong and weak road safety aspects. From a methodological point of view, this layered hierarchy allows a researcher to incorporate weight boundaries that should apply to particular layers only.

Figure 2: Index creation based on a hierarchy of indicators

4 CONCLUSION
In this paper, the value of using indicators for the road safety field has been illustrated. Indicators are useful in terms of communication, benchmarking, monitoring, etc. However, given the multidisciplinary and complex character of the road safety phenomenon, numerous indicators can
be listed. In order to keep an overview and guarantee a well-balanced indicator set in which the main aspects are represented, a theoretical framework is to be used.

In this paper, a hierarchical road safety indicator framework has been presented. On the one hand, this framework provides a clear structure in the extensive set of relevant road safety indicators; on the other hand, it offers an interesting starting point for indicator (and index) analysis. First, four main categories were listed. In particular, a good road safety indicator set should consist of outcome as well as risk, policy and background indicators. Subsequently, each category was further divided into more specific aspects.

Next, the benefits of combining indicators in an index were discussed. After showing the eight necessary steps in creating an index, the idea of the hierarchy of indicators needed to be incorporated with the index methodology. Therefore, the index methodology has to be applied repeatedly.

In the future, the conceptual ideas discussed in this paper will be further explored. In particular, the hierarchical road safety indicator framework will be filled out. Next, data for the selected indicators will be gathered and analysed. With respect to the combination of a hierarchy of indicators several indexes and an overall road safety index could be created and interpreted. Moreover, the impact of creating indexes out of other indexes will be assessed by means of uncertainty and sensitivity analysis.

REFERENCES
Commission of the European Communities.
European Road Safety Observatory (2006). Quantitative road safety targets.
European Transport Safety Council (2001). Transport safety indicators. ETSC.


Organisation for Economic Co-operation and Development (2001). Performance indicators for the road sector: Summary of the field tests. OECD.


ABSTRACT
At present, comparisons between countries in terms of their road safety performance are widely conducted in order to better understand one's own safety situation and to learn from other countries. In this respect, crash data such as the number of road fatalities and casualties are mostly investigated. However, the absolute numbers are not directly comparable between countries. Therefore, the concept of risk, which is defined as the ratio of road safety outcomes and some measure of exposure (e.g., the population size, the number of vehicles, or kilometres travelled), is often used in the context of benchmarking. Nevertheless, these risk indicators are not consistent in most cases. In other words, countries may have different evaluation results or ranking positions using different exposure information. In this study, data envelopment analysis (DEA) as a performance measurement technique is adopted to provide an overall perspective on a country’s road safety situation, and further assess whether the road safety outcomes registered in a country correspond to the numbers that can be expected based on the level of exposure. More specifically, 2007 data for 26 European Union (EU) countries (except Malta) in terms of the number of inhabitants, passenger cars and passenger-kilometres travelled are used as the model’s inputs and the number of road fatalities as the output. As a result, an overall road safety efficiency score is computed for each country and the ranking of countries in accordance with their efficiency scores is evaluated. Furthermore, based on the model results, best-performing and underperforming countries are identified, and specific benchmarks are indicated for each underperforming country. Moreover, challenging targets are given for each underperforming country by learning from its benchmarks, enabling policymakers to recognize the gap with other countries and further develop its own road safety policy.

1 INTRODUCTION
Road safety is an important issue not only because of the lost travel time or cost of property damage, but mainly because of the loss of human life and serious injuries sustained. Since more and more countries are taking steps to improve their road safety situation, there is a growing need for a country to compare its own road safety performance with that of other countries for the purpose of better understanding its relative safety situation, and moreover, trying to learn from those better-performing countries in terms of road safety policy making and target setting [OECD, 1994].
Currently, the road safety situation of a country is mostly evaluated by means of crash data such as the number of road fatalities and casualties. However, the absolute numbers are not directly comparable between countries. Therefore, the concept of risk [ETSC, 2003], which is defined as the ratio of road safety outcomes and some measure of exposure, is often used in the context of benchmarking. The number of fatalities per million inhabitants, the number of fatalities per million passenger cars, and the number of fatalities per 10 billion passenger-kilometres travelled (pkm) are three widely used risk indicators [EC, 2009]. However, they are not consistent in most cases. In other words, countries may have different evaluation results or ranking positions using different exposure information, which baffles the decision makers in distinguishing best-performing countries from underperforming countries. Moreover, from the target setting point of view, numbers rather than rates are much more preferred since a declining rate such as the fatalities per numbers of passenger-kilometres travelled may conceal an increase in the raw number of fatalities [ERSO, 2006]. Consequently, an analytical research tool that can represent an overall perspective on a country’s road safety situation (in ratio, which makes countries comparable), but is also able to provide improvement potential for those underperforming countries (by numbers), is valuable.

In this study, data envelopment analysis (DEA) as a performance measurement technique is adopted to show an overall road safety picture by taking all three aspects of exposure into account. It further assesses whether the road safety outcomes registered in a country correspond to the numbers that can be expected based on the level of exposure. More specifically, by means of this multi-input multi-output methodology the most optimal performance of a particular country is determined in terms of efficiency (i.e., an efficient transformation of input or exposure into output or road safety outcomes) thereby using the information on all other countries in the data set, i.e., it is based on relative self appraisal. Moreover, based on the efficiency score, best-performing and underperforming countries can be identified and challenging targets can be set for each underperforming country.

In this paper, the data for 26 European Union (EU) countries (the EU27 except Malta) in terms of the number of inhabitants, passenger cars and passenger-kilometres travelled are used as the model’s inputs and the number of road fatalities as the output (the number of serious casualties is also a possible output. However, a larger amount of uncertainty is linked to this variable as its definition often differs across countries, which makes the data less reliable and comparable). As a result, an overall road safety efficiency score is computed for each country and the ranking of countries in accordance with their efficiency score is evaluated. Furthermore, based on the model results challenging targets can be given for those underperforming countries by learning from their benchmarks enabling policymakers to recognize the gap with those best-performing countries and further develop their own road safety policy.

The remaining of the paper is structured as follows. In Section 2, three main risk indicators, i.e., the mortality rate, the fatality risk and the fatality rate, are introduced. The idea of setting quantitative road safety targets is presented in Section 3. Section 4 illuminates the advantages of using the DEA approach and specifies its different mathematical forms. The applications of DEA to the road safety context and the results from the model are provided and discussed in Section 5. The conclusions are summarized in Section 6 along with guidelines for future research.

2 RISK INDICATORS
Reduction of risk and consequent death, injury and damage is the key objective of policy concerning road safety. In order to obtain numerically reliable estimates of risk to road users,
recorded numbers of fatalities or casualties are usually related to measures of exposure to risk, which is the main form of risk assessment in road transport between countries [ETSC, 2003].

Concerning exposure to risk, population data are most commonly used since nearly all countries have accurate data. The corresponding risk indicator, i.e., the number of fatalities per million inhabitants, is known as the mortality rate and regarded as an important criterion for road safety. However, for the comparison of traffic risks this indicator has the disadvantage of leaving the level of motorization out of account. Accordingly, estimation of exposure to risk in terms of traffic volume is introduced representing the fatality risk, which is defined as the number of fatalities per vehicle or passenger kilometres travelled. However, the definition of this exposure measure differs widely across countries. Furthermore, not all countries collect data on motor vehicle use. As a result, a third risk indicator—defined as the number of fatalities per million passenger cars, which is also called the fatality rate—are substituted.

In the latest EU energy and transport in figures report [EC, 2009], 2007 data related to the above three risk indicators were collected for the 27 EU countries, which are Austria (AT), Belgium (BE), Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (EL), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Malta (MT), the Netherlands (NL), Romania (RO), Poland (PL), Portugal (PT), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), and United Kingdom (UK). Country rankings in decreasing order of safety are shown in Table 1.

Table 1: Rankings of the 27 EU countries based on the three road safety risk indicators in 2007 [EC, 2009]

<table>
<thead>
<tr>
<th>Fatalities per million inhabitants</th>
<th>Fatalities per 10 billion pkm</th>
<th>Fatalities per million passenger cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>MT 29</td>
<td>UK 44</td>
<td>MT 54</td>
</tr>
<tr>
<td>NL 43</td>
<td>SE 46</td>
<td>NL 97</td>
</tr>
<tr>
<td>UK 50</td>
<td>NL 47</td>
<td>UK 106</td>
</tr>
<tr>
<td>SE 51</td>
<td>MT 56</td>
<td>SE 111</td>
</tr>
<tr>
<td>DE 60</td>
<td>DE 56</td>
<td>DE 120</td>
</tr>
<tr>
<td>FI 72</td>
<td>FI 59</td>
<td>LU 135</td>
</tr>
<tr>
<td>DK 74</td>
<td>FR 62</td>
<td>IT 145</td>
</tr>
<tr>
<td>FR 75</td>
<td>LU 64</td>
<td>FR 148</td>
</tr>
<tr>
<td>IE 78</td>
<td>IT 64</td>
<td>FI 150</td>
</tr>
<tr>
<td>AT 83</td>
<td>DK 72</td>
<td>AT 164</td>
</tr>
<tr>
<td>ES 85</td>
<td>IE 80</td>
<td>ES 179</td>
</tr>
<tr>
<td><strong>EU27 86</strong></td>
<td><strong>EU27 88</strong></td>
<td><strong>IE 182</strong></td>
</tr>
<tr>
<td>IT 86</td>
<td>BE 94</td>
<td><strong>EU27 187</strong></td>
</tr>
<tr>
<td>LU 90</td>
<td>AT 94</td>
<td>DK 199</td>
</tr>
<tr>
<td>PT 92</td>
<td>ES 108</td>
<td>BE 213</td>
</tr>
<tr>
<td>BE 100</td>
<td>SI 125</td>
<td>PT 225</td>
</tr>
<tr>
<td>CY 114</td>
<td>PT 128</td>
<td>CY 227</td>
</tr>
<tr>
<td>SK 116</td>
<td>EL 158</td>
<td>CZ 291</td>
</tr>
<tr>
<td>CZ 118</td>
<td>CY 158</td>
<td>SI 293</td>
</tr>
<tr>
<td>HU 123</td>
<td>CZ 163</td>
<td>EL 338</td>
</tr>
<tr>
<td>RO 130</td>
<td>LT 187</td>
<td>EE 364</td>
</tr>
<tr>
<td>BG 131</td>
<td>EE 193</td>
<td>PL 399</td>
</tr>
</tbody>
</table>
It can be seen that the ranking positions of these 27 EU countries based on the three risk indicators are different to a great extent. For example, UK ranks first with respect to the fatalities per 10 billion pkm, however, it is not the case when considering the other two exposure information. In fact, it happens to almost all of the countries. Such kind of inconsistencies baffles the decision makers in identifying best-performing countries and deciding the extent to which these countries can be learned from. Consequently, an analytical research tool that can provide an overall perspective on a country’s road safety situation is valuable. In this study, data envelopment analysis will be adopted to show an overall road safety picture by taking all three aspects of the exposure into account\(^1\). Using the model linking inputs with outputs, the most optimal performance of each country will be determined in terms of efficiency, and the ranking of countries in accordance with their efficiency score will be evaluated (see Sections 4 and 5).

### 3 TARGET SETTING

If we argue that risk analysis makes a powerful contribution to the development of effective strategies and programmes for casualty reduction and crash prevention, then the setting of challenging yet achievable quantitative road safety targets (usually expressed in terms of final outcomes, e.g., reduction in the number of fatalities and serious injuries) serves as a significant catalyst that motivates the whole range of stakeholders (from individuals who use the roads in different ways to government agencies at all levels) to support such strategies and programmes to achieve the safer use of roads. The value of setting targets to reduce road fatalities and casualties and thereby improve road safety performance has been widely recognized [e.g., Elvik, 2001; Wong, 2006]. An increasing number of countries are implementing long term road safety strategies towards their reduction or eventual elimination (e.g., the Swedish Vision Zero [OECD/ITF, 2008]) within a framework of quantitative road safety targets.

In practice, setting a challenging yet achievable quantitative target, however, is by no means easy. Firstly, road safety targets represent the desired road safety results which a country wishes to achieve over a given timeframe. In other words, it requires a reasonable assumption about the future. However, estimates of what is likely to be achievable should not only be based upon information about the current road safety situation of a country itself (which is mostly concentrated on in the current research, such as [OECD, 2002]), but also try to incorporate other homogeneous countries’ best practices.

---

\(^1\) Even though these three aspects are highly correlated, omitting anyone can have a major influence on the computed efficiency measures [Jenkins, 2003].
In this study, a new methodology is proposed to help setting valuable numerical road safety targets for underperforming countries. More specifically, by means of data envelopment analysis, the road safety outcomes registered in a country will be assessed based on its level of exposure, and a challenging target or improvement potential will be proposed using the information on all other countries in the data set. In other words, it will base the target of a particular country on the achievements that have already been realized by so-called best-performing countries.

4 DATA ENVELOPMENT ANALYSIS

Data envelopment analysis developed by Charnes, Cooper and Rhodes [Charnes et al., 1978] is a mathematical programming methodology to measure the relative efficiency of a homogeneous set of decision making units (DMUs), or countries in this case. Since its first introduction in 1978, DEA has been quickly recognized as a powerful analytical research tool for modeling operational processes in terms of performance evaluations, e.g., [Cherchye et al., 2006], benchmarking, e.g., [Hermans et al., 2009], and decision making, e.g., [Ertay et al., 2005], and it has been successfully applied to a host of different types of entities engaged in a wide variety of activities in many contexts [Emrouznejad et al., 2008]. In the following sections, advantages of using DEA and its different mathematical forms are presented.

4.1 Advantages of DEA

DEA as a powerful performance measurement technique has received significant attention in recent years due to its prominent advantages over other traditional methods. First of all, it provides a new way of obtaining empirical estimates of relations between multiple inputs and multiple outputs without resorting to a priori knowledge concerning their weights, and the inputs and outputs used in the model can be expressed in different units of measurement. In other words, the preliminary normalization (e.g., standardization) of raw data is not required, which is particularly convenient from a practical point of view and reduces the sensitivity of the results with respect to the specific normalization scheme that is used [Nardo et al, 2005]. Moreover, DEA assesses the relative efficiency of a particular unit (or country) by comparing it against all other ones, i.e., it is based on self appraisal, and the final efficiency score will be measured with respect to the best observed performance, which is different from other techniques that are based on the average observed or some predetermined performance [El-Mahgary et al, 1995]. Last but not least, by distinguishing between efficient units and inefficient units, DEA possesses the ability to determine the potential improvement for those inefficient units by indicating practical targets for them, which mostly attracts analysts and policy makers, and results in the widespread application of this technique [Amirteimoori et al, 2005, Hermans et al, 2009, Yang et al, 2009].

4.2 The primal DEA model

Mathematically, consider a set of $n$ countries, each consuming $m$ different inputs to produce $s$ different outputs. The relative efficiency of a country is defined as the ratio of its total weighted output to its total weighted input, and the efficiency score of a particular country $c$, i.e., $h_c$, can be obtained by solving the following constrained optimization problem:
where \( y_{rj} \) and \( x_{ij} \) are the \( r \)th output and \( i \)th input respectively of the \( j \)th country, \( u_r \) is the weight given to output \( r \), \( v_i \) is the weight given to input \( i \), and \( \varepsilon \) is a small non-Archimedean number [Charnes et al., 1984] for restricting the model to assign a weight of 0 to unfavorable factors. This fractional program is computed separately for each country to determine its optimal weights. In other words, the weights in the objective function are chosen to maximize the value of country \( c \)'s efficiency ratio and meanwhile respect the less than unity constraint for all the countries including \( c \) itself. This effectively eliminates the difficult task of assigning suitable weights to each input and output factor.

Moreover, to simplify the calculation and avoid an infinite number of solutions\(^2\), the above fractional program can be converted into a linear program which is known as the multiplier form of this problem:

\[
\begin{align*}
\max h_c &= \sum_{r=1}^{s} u_r y_{rc} \\
\text{s.t.} \quad &\sum_{i=1}^{m} v_i x_{ic} = 1, \\
&\sum_{i=1}^{m} v_i x_{ij} \leq \sum_{r=1}^{s} u_r y_{rj}, \quad j = 1, \ldots, n \\
&u_r, v_i \geq \varepsilon, \quad r = 1, \ldots, s, \quad i = 1, \ldots, m
\end{align*}
\] (2)

The transformation is completed by constraining the efficiency ratio denominator in model (1) to a value of one. This model is run \( n \) times to identify the relative efficiency score of all countries by selecting optimal output and input weights. In general, a country is considered to be best-performing or efficient if it obtains an efficiency score of one whereas a score less than one implies that it is an underperforming country.

4.3 The dual DEA model
Using the duality in linear programming, we can derive an equivalent envelopment form of the above problem, which can be formulated as follows:

\[\text{If } (u^*, v^*) \text{ is an optimal solution, then } (\alpha u^*, \alpha v^*) \text{ is also optimal for } \alpha > 0 \text{ [Cooper et al., 2004].}\]

\(^2\) If \((u^*, v^*)\) is an optimal solution, then \((\alpha u^*, \alpha v^*)\) is also optimal for \(\alpha > 0\) [Cooper et al., 2004].
\[
\min \theta \\
\text{s.t.} \sum_{j=1}^{n} x_{ij} \lambda_j \leq \theta x_{ic}, \quad i = 1, \ldots, m \\
\sum_{j=1}^{n} y_{ij} \lambda_j \geq y_{ic}, \quad r = 1, \ldots, s \\
\lambda_j \geq 0, \quad j = 1, \ldots, n
\]

where \( \theta \) is a scalar and \( \lambda \) is a \( n \times 1 \) nonnegative vector of constants.

Conceptually, the dual attempts to construct for each country a hypothetical composite unit (HCU) that outperforms it. The composite unit produces outputs that are at least equal to the corresponding outputs of a particular country \( c \) and consumes at most a proportion \( \theta \) of its inputs \((0 < \theta \leq 1)\). The intensity factor \( \theta \) can thus be used to determine the minimum amount by which the inputs must be proportionally reduced for the country \( c \) to become efficient, and its value will be the same as \( h \) calculated in (2) with a value of one indicating a best-performing country. Moreover, for those countries that contribute to the construction of the HCU, they will have non-zero dual weights, i.e., \( \lambda \), and make up the reference set for country \( c \) [El-Mahgary et al., 1995].

5 APPLICATION AND RESULTS

In this study, the DEA approach is employed to show an overall road safety picture of a set of European countries, and to further assess whether the road safety outcomes registered in a country correspond to the numbers that can be expected based on the level of exposure. In doing so, we first collected data for the 27 EU countries in terms of three common measures of exposure to risk, i.e., the number of inhabitants, passenger cars and passenger-kilometres travelled, as well as the number of road fatalities in 2007 [EC, 2009]. Unfortunately, the initial examination revealed the very distinct nature of the data for Malta and consequently it was decided to eliminate this outlier and only consider 26 EU countries.

Furthermore, as opposed to other fields such as economics, in this case, we want the output---road safety fatalities---to be as low as possible. Hence, the ratio of the weighted input (or exposure) to the weighted output (or fatalities) will be maximized. The overall optimal road safety efficiency score for each of the 26 EU countries from either the primal or the dual DEA model is presented in Table 2.

Table 2: Optimal road safety efficiency scores of the 26 EU countries based on DEA

<table>
<thead>
<tr>
<th>Country</th>
<th>Efficiency score</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>1</td>
</tr>
<tr>
<td>UK</td>
<td>1</td>
</tr>
<tr>
<td>SE</td>
<td>0.9605</td>
</tr>
<tr>
<td>DE</td>
<td>0.8232</td>
</tr>
<tr>
<td>FI</td>
<td>0.7490</td>
</tr>
<tr>
<td>LU</td>
<td>0.7273</td>
</tr>
<tr>
<td>FR</td>
<td>0.7095</td>
</tr>
<tr>
<td>IT</td>
<td>0.7020</td>
</tr>
<tr>
<td>DK</td>
<td>0.6277</td>
</tr>
</tbody>
</table>
It can be seen that the Netherlands and United Kingdom are the only two best-performing countries since they obtain the optimal efficiency score of one, which means that they are at the top of the countries’ performance ranking, while the remaining 24 countries (obtaining values less than one) are considered to be underperforming and can be ranked by their scores directly. Moreover, comparing the ranking result with the ones in Table 1, which are based on the three risk indicators separately, we find that the result from the DEA model gives us a global view on the country’s road safety efficiency by taking all three aspects of exposure into account, and yet it is not the simple average of those three rankings.

To better understand the computational process leading to the efficiency scores presented in Table 2, and especially the reasons why the 24 underperforming countries are unable to obtain a value of one, we can further explore the mechanism of the primal and dual DEA approach, respectively. Theoretically, the primal DEA model is to choose the best possible input and output weights under the imposed restrictions to maximize the efficiency score of a certain country. If the optimal weights of a country $A$ under study do not result in a value of one for this country but cause the weighted score of another country $B$ in the data set to become one, then the model stops. This implies that country $B$ is characterized by a lower risk than country $A$ with respect to at least one of the exposure aspects since the efficiency score of $B$ is relatively higher with the same set of weights. Therefore, country $A$ could take country $B$ as an example for improving its road safety performance. From the dual DEA model’s point of view, the dual weights, i.e., $\lambda$, can be viewed as indicating the amount of technical weight that is attributed by each benchmark country in the construction of an efficient HCU. In other words, the countries with non-zero dual weights make up the reference set for the country under study. Using this principle, the reference sets and dual weights of all 24 underperforming countries are indicated in the second and third column of Table 3. In the remaining two columns, the registered number of fatalities in 2007 and the proposed targets are presented for these countries, which will be discussed below.
Table 3: Reference sets and targets for the 24 underperforming countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Ordered reference set</th>
<th>Dual weights ($\lambda$)</th>
<th>Fatalities in 2007</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE</td>
<td>{NL, UK}</td>
<td>0.284, 0.102</td>
<td>1067</td>
<td>512.22</td>
</tr>
<tr>
<td>BG</td>
<td>{NL}</td>
<td>0.468</td>
<td>1006</td>
<td>331.52</td>
</tr>
<tr>
<td>CZ</td>
<td>{NL}</td>
<td>0.631</td>
<td>1221</td>
<td>447.26</td>
</tr>
<tr>
<td>DK</td>
<td>{NL, UK}</td>
<td>0.169, 0.044</td>
<td>406</td>
<td>254.83</td>
</tr>
<tr>
<td>DE</td>
<td>{NL, UK}</td>
<td>4.268, 0.343</td>
<td>4949</td>
<td>4073.92</td>
</tr>
<tr>
<td>EE</td>
<td>{NL}</td>
<td>0.082</td>
<td>196</td>
<td>58.07</td>
</tr>
<tr>
<td>IE</td>
<td>{NL, UK}</td>
<td>0.205, 0.016</td>
<td>338</td>
<td>195.36</td>
</tr>
<tr>
<td>EL</td>
<td>{NL}</td>
<td>0.683</td>
<td>1580</td>
<td>484.42</td>
</tr>
<tr>
<td>ES</td>
<td>{NL}</td>
<td>2.918</td>
<td>3821</td>
<td>2068.94</td>
</tr>
<tr>
<td>FR</td>
<td>{UK, NL}</td>
<td>0.973, 0.426</td>
<td>4620</td>
<td>3277.83</td>
</tr>
<tr>
<td>IT</td>
<td>{NL, UK}</td>
<td>2.383, 0.625</td>
<td>5131</td>
<td>3602.25</td>
</tr>
<tr>
<td>CY</td>
<td>{NL}</td>
<td>0.054</td>
<td>89</td>
<td>38.01</td>
</tr>
<tr>
<td>LV</td>
<td>{NL}</td>
<td>0.139</td>
<td>419</td>
<td>98.51</td>
</tr>
<tr>
<td>LT</td>
<td>{UK}</td>
<td>0.057</td>
<td>739</td>
<td>173.88</td>
</tr>
<tr>
<td>LU</td>
<td>{NL, UK}</td>
<td>0.037, 0.002</td>
<td>43</td>
<td>31.27</td>
</tr>
<tr>
<td>HU</td>
<td>{NL}</td>
<td>0.614</td>
<td>1232</td>
<td>435.21</td>
</tr>
<tr>
<td>AT</td>
<td>{NL}</td>
<td>0.578</td>
<td>691</td>
<td>409.75</td>
</tr>
<tr>
<td>PL</td>
<td>{NL}</td>
<td>2.327</td>
<td>5583</td>
<td>1649.86</td>
</tr>
<tr>
<td>PT</td>
<td>{NL}</td>
<td>0.648</td>
<td>974</td>
<td>459.13</td>
</tr>
<tr>
<td>RO</td>
<td>{NL}</td>
<td>1.315</td>
<td>2794</td>
<td>932.55</td>
</tr>
<tr>
<td>SI</td>
<td>{NL, UK}</td>
<td>0.028, 0.027</td>
<td>292</td>
<td>103.77</td>
</tr>
<tr>
<td>SK</td>
<td>{NL}</td>
<td>0.329</td>
<td>627</td>
<td>233.60</td>
</tr>
<tr>
<td>FI</td>
<td>{UK}</td>
<td>0.093</td>
<td>380</td>
<td>284.61</td>
</tr>
<tr>
<td>SE</td>
<td>{UK, NL}</td>
<td>0.135, 0.055</td>
<td>471</td>
<td>452.42</td>
</tr>
</tbody>
</table>

Firstly, it can be seen that the reference set for each underperforming country is solely comprised of one or both of the two best-performing countries, i.e., the Netherlands and United Kingdom. Totally, 22 times NL acts as a benchmark country while 11 times UK.

Moreover, since the value of the dual weight points out the extent to which each benchmark country contributes to the definition of the HCU for each underperforming country, it enables us to rank the benchmark countries in terms of their relative importance. Taking Belgium as an example, the dual weight of NL (0.284) is more than twice as large as that of UK (0.102) implying that NL plays a stronger role in determining the ideal performance of Belgium.

More importantly, the constructed HCU offers information for setting a challenging target for each underperforming country in order to become efficient. In other words, for each underperforming country, a quantitative road safety target can be formulated by learning from its benchmarks, using the following formula:

$$T_j = \lambda_{\text{NL}} F_{\text{NL}} + \lambda_{\text{UK}} F_{\text{UK}} \quad j = 1, \ldots, n \quad (4)$$

where $T_j$ denotes the target number of fatalities for the $j$th underperforming country. $F_{\text{NL}}$ and $F_{\text{UK}}$ are the number of fatalities in NL and UK in 2007, which were 709 and 3058, respectively. Thus, for the case of Belgium, its target number of fatalities can be calculated as:
In other words, Belgium is currently only half way (compared to its current figure of 1067) to belong to the group of best-performing countries in the EU. Furthermore, for the whole EU Member States, the overall target (summing up the target values of the 24 EU countries in Table 4 together with the current values of NL, UK and MT) would be 24,388, while its figure in 2007 was 42,448, which means that it could be reduced 42.55% if all countries were as efficient as NL and UK. Therefore, greater efforts are needed, at both the European and national levels.

6 CONCLUSION
Road traffic injuries and fatalities will continue to be one of the most serious public health issues within the next decade. In order to make progress in road safety, countries need to evaluate their own safety performance, compare it with that of other countries, and further learn from those best-performing ones by indicating challenging quantitative targets and action programmes for themselves. In this paper, the research on data envelopment analysis is presented to measure and compare the efficiency of 26 EU countries by taking three main risk indicators (i.e., the number of fatalities per million inhabitants, the number of fatalities per million passenger cars, and the number of fatalities per 10 billion passenger-kilometres travelled) into account simultaneously. Applying the model linking input (or exposure to risk) and output (or the number of fatalities), an overall optimal road safety efficiency score is computed for each country considering the information on all other countries in the data set. Moreover, based on the model results, best-performing and underperforming countries could be identified, and benchmarks for those underperforming ones indicated. More importantly, the extent to which the benchmarks could be learned from has been specified, and a challenging target or improvement potential has been given for each underperforming country.

In the future, more aspects could be investigated. Firstly, other inputs or outputs could be used to describe road safety, e.g., safety performance indicators and policy performance indicators [Wegman et al., 2008; Tingvall et al., 2010], which could enable policymakers to prioritize their investments to enhance the level of road safety. Secondly, uncertainty and sensitivity analysis should be conducted to reveal the impact of a change in data set, for example, regarding input/output specification, sample size, and data quality. Thirdly, DEA is suitable for country comparisons over time as well, which makes it possible to set quantitative targets for the benchmark countries since the best performing country in one year may not be best the next year. Moreover, for the most underperforming countries, rather than only specifying one single, probably hard to achieve target, several more realistic ones, especially for short or medium terms, should be taken into account, which can be realized by using the categorical DEA model. Finally, from the road safety policy point of view, we should keep in mind that setting targets does not guarantee their achievement unless keeping adequate political ambition, effective strategies, sufficient allocation of resources, successful implementation, and persistent monitoring and evaluation as an ongoing process throughout the whole target period.

REFERENCES


EVALUATION OF METHODS FOR PEDESTRIAN SAFETY IMPROVEMENT ON LEFT-TURNING VEHICLES MOVEMENT

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ABSTRACT
Warning systems are being developed for left-turning vehicles at intersections where protected left-turns are not warranted or cannot be provided, based on limitations of right of way or intersection capacity. These are meant to provide warnings to left-turning vehicles of vehicles approaching from the opposite direction, when the time to turn may be deemed unsafe. To implement these warning systems, it is necessary to estimate in near real time, the probability of conflict between the two approaching vehicles. A study is being conducted with the help of video and radar at various intersections, to obtain estimates of turning time and acceptable gaps for drivers under various situations. Initial pilot observations indicate that the presence of pedestrians in intersections had an immediate and substantial impact on movement of left turning vehicles. From a preliminary systematic video analysis of the intersection, in the presence of pedestrians on the destination crosswalk, the mean and standard deviation of both the gap and gap components (i.e., turning time and the “buffer” between the turning vehicle and the next oncoming vehicle) increased. On the basis of these observations, pedestrian-detection mechanisms may be useful in such intersection warning systems, with a threshold for warning that is adjusted for pedestrians when they are present or in the vicinity of the destination crosswalk.

1 INTRODUCTION
The Consortium of Iran road and transportation institute(affiliated to Iran ministry of road and transportation) and universities is developing infrastructure-based and cooperative Intersection Decision Support (IDS) systems(Zennaro and Misener). Within this Consortium, the Islamic azad university, Karaj branch, transportation engineering proposal project Program and Iran road and transportation institute are working to develop systems that help drivers avoid major types of crashes that are associated with left turns at intersections. Traditional countermeasures to crossing-path crashes create protected left turn movements through channelization and offset. In urban areas, however, such efforts to protect left-turning drivers may be prevented due to difficulties obtaining the right-of-way to install dedicated left-turn lanes or reducing the capacity of signalized intersections by providing an additional protected left-turn phase. Drivers at permissive left-turn intersections, especially at intersections with inadequate sight lines, are often exposed to conflicts or crashes with other vehicles. Importantly, human perception is limited, and many drivers have difficulty judging the speed of oncoming vehicles. Consequently, drivers who underestimate the time they need
can lead to conflict with other vehicles as they turn left across the path of oncoming vehicles (i.e., “left turn across path/opposite direction” or LTAP/OD). Concerns about inaccurate judgments are especially true for older drivers (Staplin and Hakamies). In order to overcome the problem, an IDS system is being developed to warn drivers when there is insufficient time to make the left turn (Najm). LTAP-OD crashes account for 18 percent of collisions at signalized intersections, and 6.7 percent of all crossing-path crashes (David). Overall, crossing-path crashes at intersections comprise over 25 percent of the crashes in the IRAN. The LTAP/OD problem is prevalent, particularly with older drivers (Hakamies) and in urban settings (David). The current study on the impact of pedestrian presence on the movement of left-turning vehicles at intersections is based on the LTAP/OD crash scenario.

In the design of an effective IDS system, it is necessary to predict potential conflicts by detecting the motions of the turning vehicle (termed the Subject Vehicle, or SV) and of the vehicles with which it may be in conflict (termed Principal Other Vehicle/s, or POV). For the case of the LTAP/OD, the POV comes from the direction opposite as shown in the photograph in the diagram in Figure 1.

![Figure 1: Layout of intersection and the various agents of the study](image)

When the available gap between the SV and an approaching POV is not adequate for completing a safe turn, the IDS system can alert the SV driver based on its prediction of the conflict. The alert needs to be activated early enough to give the SV driver time to stop before coming into conflict with a POV. However, it should not be so early that it will be perceived as a nuisance or that it will deter drivers from completing safe turns. While developing the warning system for IDS, researchers observed that the presence of pedestrians in or near the destination crosswalk influences turning times for the SV. This would be an important effect to be accounted in the warning system design. Normally, pedestrians cross intersections simultaneously with movement of a parallel stream of vehicles. Although this results in little conflict between pedestrians and vehicles passing straight through the intersection, pedestrians may still lead to conflict with turning vehicles. Drivers of the turning vehicles must therefore wait until crossing pedestrians depart from the path of the turning vehicle before they can safely turn. Presence of pedestrians clearly affects the turning times of left-turning vehicles. Moreover, the presence of pedestrians can create a conflict: The driver may feel pressure to turn, especially if he or she is in a lane shared with through traffic and if the driver is in a left turn pocket if a queue follows. Further, the driver may not notice the pedestrian since he or she may be focused on judging gaps between oncoming vehicles. As a result, the turning vehicle may be ‘stranded’ in the possible path of the POV, waiting for the pedestrian to clear its path.

In this study, we observe how pedestrian presence affects the movement of turning vehicles, especially left turning vehicles, and note its implications for various IDS countermeasures to be used in intersections. The present study is designed to: (i) describe a methodology for
assessing the impact of pedestrian presence on SV and POV movement and interaction, (ii) provide some preliminary quantitative results, (iii) describe general implications for safety and capacity at intersections, and (iv) describe specific implications for LTAP-OD advisory systems.

2 REVIEW OF PUBLISHED EVIDENCE
Of the literature relevant to this study (White) discusses various intersections where IDS measures were notionally applied. Published literature relating to conflicts and crashes at intersections that involve pedestrians and bicycles is not directly relevant since it deals mostly with evaluating effects of intersection configuration (Lord), geometric improvements, signage, road markings and traffic control devices. A study dealing with human factors contributing to left-turning vehicles crashing with pedestrians concluded that a pedestrian is four times more likely to be hit by a left-turning vehicle than by a right-turning vehicle. Drivers and pedestrians, or both in cases when the vehicle is turning left, could have poorer perception of other road users, compared to the case of a through moving or a right turning vehicle, which contributes to potential conflicts.

There is very little literature on the impact of pedestrian presence on the movement of vehicles at intersections. A study by Rouphail, et al. examined parts of the 1994 Highway Capacity Manual (HCM) that relate to interactions between pedestrians and turning vehicles. The study concluded that there are variations in vehicular saturation flow due to pedestrians. The manual further noted that the HCM might not accurately predict the effect of a moderate pedestrian or bicycle volume on turning traffic. It suggested procedures that should improve the analysis and performance of signalized intersections, subject to non-motorized interference with turning movements. It further recommends that the HCM use the saturation flow adjustment factors determined by the study and use the findings of the study in its chapters on signalized intersections and on pedestrians. The 2000 Highway Capacity Manual incorporates these recommendations. However, the focus of the Rouphail study is on capacity issues rather than safety.

3 METHODS
3.1 Video observation
To observe the movements of the vehicles at intersections, we have used video cameras and automotive Doppler radars, temporarily mounted at the roadside at typical intersections. (Chan and Shladove) The current report presents analysis of video data exclusively. The video data are used primarily to quantify the behavior of the SV. The typical placement of video camera at an intersection is shown in Figure 2.

![Figure 2: Video Data Collection Fields of View](image_url)
The extraction of the SV movement data from the video images is complicated by the wide variety of driver actions at intersections where pedestrians are crossing. In some situations, drivers proceed dangerously through a left turn at an intersection without stopping; while in others, drivers cautiously halt at the stop line, and they wait to turn until there is suitable gap in the opposing traffic and all pedestrians have cleared the vehicle’s projected path. Some drivers gradually move forward into the intersection, while others drive directly into the middle of the intersection before stopping to wait for the desired gap between POV and pedestrians crossing its path.

For the purpose of analysis, the intersection is subdivided into regions in order to facilitate a systematic description of the paths that the vehicles follow, as shown in Figure 3.

Figure 3: Different points in an intersection label turning path of SV

3.2 Extraction of turning times using the observation tool/intersection diagram

To enable the analyst to identify specific times from the video data efficiently (for example to identify the times at which the vehicle is at any of the seven points defined in Figure 3), we developed a video “playback” tool. The tool can be used to modify the speed of the video playback and record the timeline by clicking on the numbered icons. It is essentially a Quicktime video player with variable speed and adjustable frame speed capabilities that allows the analyst to mark the time of events relative to the beginning to the segment of the video. The initial data collection for the LTAP/OD scenario was conducted at a signalized intersection (Valiasr and Enghelabe-eslami Ave) in the City of Tehran. The turning SV has a left-turn pocket, but the intersection does not have a protected left-turn signal phase, and so the SV driver must turn across two lanes of opposing traffic during the green signal cycle.

4 THE STUDY SITE

Located in the northeast part of northern Tehran, Valiasr runs North-South and Enghelabe-eslami runs East-West. Both roads have two lanes in each direction, with Valiasr having additional left turn pockets each a single lane wide. A plan view of the intersection is shown in Figure 4. The intersection has over 2000 vehicles moving through it in the peak hour. Table
Table 1: Turning movement at Valiasr - Enghelane-eslami Intersection

<table>
<thead>
<tr>
<th></th>
<th>Northbound</th>
<th>Southbound</th>
<th>Eastbound</th>
<th>Westbound</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left Thru Right</td>
<td>Left Thru Right</td>
<td>Left Thru Right</td>
<td>Left Thru Right</td>
<td></td>
</tr>
<tr>
<td>AM Peak</td>
<td>19 291 43</td>
<td>199 810 57</td>
<td>31 278 24</td>
<td>11 225 51</td>
<td>2039</td>
</tr>
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<td>PM Peak</td>
<td>34 715 63</td>
<td>117 537 54</td>
<td>67 232 20</td>
<td>122 321 136</td>
<td>2418</td>
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</tbody>
</table>

The signals at this intersection were controlled on a fixed cycle, with some variation with time of day. The cycle duration was 75 seconds during the hours of our observation. In the direction of Valiasr Ave, the green phase was 34.1 seconds long, amber 3.3 seconds, all-red 2 seconds and red for the remaining period.

The 1998-2007 crash data shows, that of the 29 collisions at Enghelabe-eslami and Valiasr, three were LTAP-OD type, and another three were left turns into pedestrians. The total number of crashes recorded for the combination of these two categories is second only to the category of signal violation that records 10 crashes.

At this site, the video data was collected on two days, November 2, 2008 and again on December 17, 2008. The data collection was conducted for approximately 90 minutes on the first day and 120 minutes on the second day, in conjunction with traffic data collection by a mobile platform using computerized data acquisition and radar. The pilot field observation was conducted in the late morning and early afternoon hours when traffic was not congested; in other words, traffic was sufficient to create a mixture of gap sizes. This allows the collection of diverse traffic patterns not biased towards congestion. The number of pedestrians crossing the destination crosswalk under observation during the survey period was found to be an average of 195 pedestrians in one hour.

5 DATA ANALYSIS & RESULTS
5.1 Turning time as a function of pedestrian presence

The first step in designing the IDS warning system is to predict when the SV will be in possible conflict with the path of the POV (i.e. when it will cross the lanes with oncoming traffic from the opposite direction). If the SV is still approaching the intersection, the time for
it to reach the threshold of the intersection may be estimated based on the speed of its
approach trajectory, as there is variability in approach trajectories. The time needed to
traverse the opposing traffic lanes from the stop bar in the SV’s original lane can be derived
from the observation data. The turning times for left turning vehicles at Valiasr and
Enghelabe-eslamie are summarized in Table 2. For the purpose of this study, turning time is
defined as the time from when the SV driver makes significant left-turn movement (point 55
on Figure 3) to the time the SV rear bumper leaves the travel way of POV (point 33 on Figure
3).

On Table 2, in the absence of pedestrians, turning times have a mean value of 3.0 seconds,
with a standard deviation of 0.5 seconds. The presence of pedestrians raises the mean turning
time to 4.4 seconds and the standard deviation to 1.5 seconds. The data with pedestrian
influence increases the mean of the total sample to 3.3 seconds and the standard deviation to 1
second. In other words, the presence of a pedestrian increases the vehicle’s average turning
time as well as the variability of the turning time.

Table 2: Observed Turning Time Statistics

<table>
<thead>
<tr>
<th>Type of Turn</th>
<th>Number of Observations</th>
<th>Mean Turning Time* (s)</th>
<th>Standard Deviation (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete data set</td>
<td>109</td>
<td>3.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Data for which pedestrian present in destination crosswalk</td>
<td>22</td>
<td>4.4</td>
<td>1.5</td>
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<tr>
<td>Data for which pedestrian absent in destination crosswalk</td>
<td>87</td>
<td>3.0</td>
<td>0.5</td>
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</table>

* Time from first significant turning to clearing POV lane

5.2 Accepted gap as a function of pedestrians present
In this study, gap is defined as the interval between the time the rear bumper of the first POV
crosses a point in the intersection to the time the front bumper of the second POV crosses the
same point. Noting the gaps between consecutive POV, in addition to noting the various
LTAP/OD movements, the data set includes gaps accepted and rejected by SV drivers under
different situations of left turns. Table 3 provides the mean and standard deviation of the gaps
accepted by SV drivers for the entire set of observations, and for observations with and
without pedestrian influence.

Table 3: Observed Accepted Gap Statistics

<table>
<thead>
<tr>
<th>Type of Turn</th>
<th>Number of Observations</th>
<th>Mean Accepted Gap‡ (s)</th>
<th>Standard Deviation (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete data set</td>
<td>28</td>
<td>8.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Data for which pedestrian present in destination crosswalk</td>
<td>8</td>
<td>11.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Data for which pedestrian absent in destination crosswalk</td>
<td>20</td>
<td>7.7</td>
<td>2.5</td>
</tr>
</tbody>
</table>

‡Time interval between clearing of the projected line of turn of SV by the rear bumper of the POV preceding the turn and that by the front bumper of the POV following the turn

The number of observations for accepted gaps (28) is significantly less than the number of
observations for turning times (109). Several observations were dropped while linking the
turning data with the gap acceptance data, primarily because for many of the left turns
undertaken, the subsequent POV arrived much later compared to the time the SV made its
turn. Those values were necessarily excluded from the analysis because they could not
represent a real influence of the POV presence on the turning decision of the SV driver. Considering these values for gap acceptance would artificially increase the mean value of the accepted gap.

Table 3 demonstrates that in the absence of pedestrians, the accepted gaps have a mean value of 7.7 seconds and a standard deviation of about 2.5 seconds. The presence of pedestrians raises the mean value of turning time to 11.4 seconds and the standard deviation to 4.4 seconds. The data with pedestrian influence increases the overall mean to 8.7 seconds and the standard deviation to 3.5 seconds.

5.3 Turning Time, Buffer and Accepted Gap

The relation of accepted gap (G) with turning time (T) and buffer (B) may be modeled for the total dataset, for the observations with pedestrians present in the destination crosswalk and those without. The accepted gap constitutes turning time and buffer time before and after the completion of the turn, i.e. $G = T + B$. (White)

The models take a polynomial form.

\[
\begin{align*}
B &= \alpha G^2 + \beta G + \gamma_1 \\
T &= \alpha_2 G^2 + \beta_2 G + \gamma_2 \\
B &= \alpha_3 T^2 + \beta_3 T + \gamma_3
\end{align*}
\]

The details of the modeled results are given in Table 4. These three combinations have a very high R² for the association between buffer and accepted gap, and significant t-statistics (except for the parameter G²). The R², however, is much lower for the relation between turning time and accepted gap, and turning time and buffer, and the T-statistics are insignificant. Of the models, the most robust models seem to be those of the observations without the pedestrians, and the least are those of the observations with pedestrians.

Plots showing turning times and buffers vs. actual accepted gaps give different results for observations. These include instances in which pedestrian presence affected the turning time as compared to instances in which such observations were eliminated. Turning movements have been disaggregated to show both components of the gap. The results of the analysis are reported in Figure 5. The observations show substantial variability about the trend line (i.e. for the same accepted gap, a rise in turning time above the trend line, is marked by a drop in buffer below the trend line and vice versa, as is expected, since the sum of buffer and turning time constitute accepted gap). Separating those observations with pedestrians and without pedestrians in the destination crosswalk demonstrates the large variability about the trend line in the total data is caused only by observations with pedestrians in the destination crosswalk. Figure 6 represents the 20 turns without pedestrians present, showing that the variability of buffer and turning time about the trend line is much less.

The consistency of the turning times can be seen from the nearly-horizontal plot of the turning times with pedestrians clustered between 3 to 6 or more seconds (Figure 5) and turning times without pedestrians clustered between less than 3 to less than 4 seconds (Figure 6). The large variability in the total accepted gap time is due to the “buffer time”. This hypothesis is also supported by the three models, in which the model of accepted gap and buffer is the only one that is statistically significant.
Figure 5: Turning Time vs. Accepted Gap for all vehicles on Valiasr- Enghelabe eslami

Figure 8: Turning Time vs. Actual Accepted Gap for vehicles without pedestrian influence on Valiasr- Enghelabe eslami
Table 4: Model of relationship between Turning Time, Buffer and Gap

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>Coefficients</th>
<th>Coefficient value</th>
<th>t-stat</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
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<td></td>
<td></td>
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<td></td>
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<td>G</td>
<td>-0.09</td>
<td>-0.34</td>
<td>-0.63</td>
<td>0.04</td>
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<td>G²</td>
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<td>-1.16</td>
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<tr>
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<td>4.17</td>
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<td>6.66</td>
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<tr>
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<td></td>
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<td>1.30</td>
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</table>

6 DISCUSSION AND CONCLUSIONS
The analysis suggests that the presence of pedestrians in the destination crosswalk increases the mean and standard deviation of the accepted gap, the buffer, or the turning time (based on definitions of these terms). These could have implications on signal timing and signal configuration and on calculations of traffic flow, as observed by Rouphail.

The small sample size of observations specific to a single intersection may introduce some bias in the data. For some of the coefficients in the models, statistical significance could not be achieved, as statistical significance depends on sample size. Also, the sample may not exhibit the desirable properties common to large samples namely convergence in distribution, consistency and asymptotic efficiency. However, the results obtained are intuitive given the nature of the problem, and could be validated as larger samples are obtained with the progress of the study. Furthermore, similar observations will be needed at a broader range of
intersections with diverse characteristics in order to define the sensitivity of pedestrian influence to intersection characteristics.

The preliminary conclusions relate to safety and capacity of the intersection in all cases and imply that the presence of pedestrians necessitates different baselines for calculations. For this, we consider the two mechanisms at work in the cases of LTAP/OD type turn in presence of pedestrians:

(a) the SV driver delays the start of the turn because s/he sees the pedestrian in the crosswalk, or
(b) the SV driver has to slow down or stop in the path of POV after initiating the turn because s/he did not see pedestrians early enough.

The former may be a safe scenario, but the latter is not. The differences are evident in different effects on the turning and the buffer times. In the first case, a large buffer time may be realized before the left turn begins, where in the second case, the turning time may be greatly increased. These will have implications on the design of the warning mechanism.

To account for pedestrians, a warning mechanism may require a supplemental warning system (e.g. warning the SV of pedestrian/s in the destination crosswalk), or the warning may be activated by pedestrian/s in the destination crosswalk just as it would be by a POV that is ‘too close’. In the absence of a system warning of pedestrians crossing the street, or in cases where the SV driver does not heed the warning, if scenario (b) occurs, an additional warning system may be required that will warn the POV of the SV in its path. In all cases however, it is important that the turning vehicle be warned of pedestrians in the destination crosswalk, which means that the warning system would require an integrated capacity for pedestrian detection. A pedestrian detection mechanism may enable a different set of warning criteria to be in effect with presence of pedestrians in the far left intersection crosswalk. Automated pedestrian detection systems may provide the means to detect the presence of pedestrians as they approach the curb before crossing the street, and then activate the pedestrian “Walk” signal without any action required on the part of the pedestrian. An emerging technology for detecting pedestrians may be adopted for this purpose. Areas of relevance include pedestrian detection mechanisms, cross-walk warning systems, and various types of pedestrian signal configurations.

REFERENCES


Tehran Traffic and Transportation Control Centre, (2009), [http://traffic.tehran.ir/](http://traffic.tehran.ir/)


MULTILEVEL DATA IN TRAFFIC SAFETY: A 5 × ST-LEVEL HIERARCHY

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ABSTRACT
Traditional crash prediction models, such as generalized linear regression model, suffer from a common underlying limitation that observations (e.g., a crash or a vehicle involvement) are treated as “independent” to each other. However, this “independence” assumption may often not hold true since multilevel data structures exist extensively because of the traffic data collection and clustering process. Disregarding the possible within-group correlations may lead to production of models with unreliable parameter estimates and statistical inferences. In this paper, a 5×ST-level hierarchy is proposed to represent the general framework of multilevel data structures in traffic safety, i.e. [Geographic region level – Traffic site level – Traffic crash level – Driver-vehicle unit level – Occupant level] × Spatiotemporal level. To properly accommodate the potential cross-level heterogeneity and spatiotemporal correlation due to the multilevel data structure, a Bayesian hierarchical approach that explicitly specifies multilevel structure and reliably yields parameter estimates is introduced and recommended. Using Bayesian hierarchical models, the results from several case studies are highlighted to show the improvements on model fitting and predictive performance over traditional models by appropriately accounting for the multilevel data structure.

Key words: Road safety, crash prediction models, Bayesian Hierarchical models, Multilevel data

INTRODUCTION
Crash prediction model (also called safety performance function) is one of the most important techniques in investigating the relationship between crash occurrence and risk factors associated with various traffic entities. These risk factors are assumed to provide information on the behavior of the crash occurrence, which is commonly measured by crash frequency with various degrees of crash severity. Appropriate probabilistic forms and statistically significant factors are identified based on the examination of crash occurrence mechanism and model fitting performance to the historical crash data. The typical structure of such models could be expressed as a general form as follows:

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\[ Y | \theta \sim \text{Dist}(\theta) \]

with \( \theta = f(X, \beta, \varepsilon) \) \hspace{1cm} (1)

- \( Y \): Dependent variable(s) of interest, e.g., crash frequency or severity
- \( \text{Dist}(\theta) \): Adapted distribution for \( Y | \theta \) and its parameter(s)
- \( X \): Covariates representing various exposure/risk factors to crash occurrence
- \( \beta \): Coefficients, i.e., factor effects of \( X \) on \( Y \)
- \( f(\cdot) \): Link function relating \( X \) and \( Y \)
- \( \varepsilon \): Disturbance/error terms in the model

The dependent variable \( Y \) is assumed to follow some distribution with parameter(s) \( \theta \), which is further modeled as a link function \( f(X, \beta, \varepsilon) \). The selection of the distribution depends on the nature of the crash features of interest. Particularly, in predicting crash frequency, Poisson distribution is traditionally employed to model the count data. In contrast, when crash severity is concerned, discrete outcome distributions are generally used, such as those in nominal models or ordered discrete models. The distribution parameters (\( \theta \)) are then related to the risk factors using a link function which in a conceptual sense, consists of three components:

i) a suitable transformation function for \( \theta \) based on the nature of data type, for example, a logistic function for binary data or exponential function for count data;

ii) an expression combining \( X \) and \( \beta \), typically assuming a linear combination of \( X \) or their transforms, i.e., \( X\beta \), and

iii) the term \( \varepsilon \) to represent various disturbance/error terms assumed in the model.

Considerable efforts have been made to investigate the suitability of various crash prediction models for both crash frequency and severity. Traditionally, generalized linear regression models (GLMs), such as Poisson model, Logit or Probit Models are broadly applied to build probabilistic formulations on the relationship of the crash occurrence with a variety of possible covariates. In most of these classical models, the disturbance term \( \varepsilon \) is inherently determined by the adapted distribution, resulting in some constraints for the mean and the variance of the model, e.g., ‘variance = mean’ in Poisson model, or ‘variance = mean \times (1\text{-mean})’ in Binomial Logit model. Hence, they may not be adequate to account for some over-dispersed data, which are commonly found in crash data. To overcome the over-dispersion problem in count data, some over-dispersed Poisson models have been proven to be useful by relaxing the condition of ‘variance = mean’ in standard Poisson model. Without explicitly distinguishing the source of over-dispersion, an additional stochastic component \( \varepsilon \) is introduced to the link function. By respectively assuming \( \exp(\varepsilon) \) a Gamma distribution or a Lognormal distribution, Poisson-Gamma model (also call Negative Binomial model, NB) or Poisson-Lognormal distribution is typically employed.

However, these GLMs suffer from a common underlying limitation that each observation (e.g., a crash or a vehicle involvement) in the estimation procedure corresponds to an individual situation. Hence, the residuals from the model exhibit independence. However, this “independence” assumption may often not hold true since multilevel data structures especially spatiotemporal structures exist extensively because of the traffic data collection and clustering.
process. Disregarding the possible cross-group heterogeneities or spatiotemporal correlations may lead to production of models with unreliable parameter estimates and statistical inferences.

In recent years, several advanced statistical techniques have been explored to more appropriately represent the nature of crash data. For example, a number of studies have employed zero-inflated models to take into account the excess zero observations in crash data, whereas Lord et al. (2005, 2007) have questioned the validity of the basic zero-state assumption in these models. In this regard, Markov switching models (Malyshkina et al. 2009; Malyshkina and Mannering 2009a, b) and finite mixture models (Park and Lord 2009) have been newly tested. Especially, the Markov switching models allow specific road entities to switch between multiple crash states over time. Furthermore, the use of variable dispersion parameters in negative binomial models have been proven useful to improve the model-fitting (Heydecker and Wu 2001; Miaou and Lord 2003; Miranda-Moreno et al., 2005; El-Basyouny and Sayed 2006; Mitra and Washington 2007; Lord and Park 2008). Multivariate count models have also been applied to jointly model crash frequency at different levels of injury severity (Park and Lord 2007; Ma et al. 2008, Aguero-Valverde and Jovanis 2009; El-Basouny and Sayed 2009). More recently, a more flexible random parameter modeling approach is emerging in literature, in which the model parameters are allowed to vary from site to site (Li 2008; Anastasopoulos and Mannering 2009; Huang et al. 2008, 2009; El-Basyouny and Sayed 2009). The emergence of aggregate crash prediction models in response to the safety conscious planning has boosted the exploration of spatiotemporal models to account for the unmeasured confounders and spatiotemporal autocorrelations among adjacent geographic units (e.g., counties, TAZs) (Miaou et al. 2003; Aguero-Valverde and Jovanis 2006; Quddus 2008; Huang et al. 2010). It is noted that most of these models have been accomplished in the methodological framework of Bayesian hierarchical approach.

Clearly, these recent advances have significantly improved the analytical capability over traditional crash prediction models. However, till now, there is no systematic and consistent examination found in literature on the multilevel data characteristics in general traffic safety research. Thus, this study aims at a comprehensive inspection of typical data used in traffic safety evaluation, especially in calibrating crash frequency/severity prediction models. Specifically, a conceptual model with a 5×ST -level hierarchy is innovatively proposed to represent the general framework of multilevel data structures in traffic safety. To properly model the potential cross-level heterogeneity due to the multilevel data structure, the Bayesian hierarchical approach that explicitly specifies multilevel structure and reliably yields parameter estimates is introduced and recommended. Finally, several recently published or accomplished studies by the current authors and their colleagues are summarized to exemplify the proposed methodology with empirical evaluation.

MULTILEVEL DATA STRUCTURE IN TRAFFIC SAFETY

A Common Neglect in Existing Models: Cross-Group Heterogeneity
To clearly explain the underlying limitation of ‘independence’ assumption in GLMs, we take an example of a simple regression relationship between crash frequency and crash exposure. The crash exposure is defined as the amount of opportunities for crashes of a certain type which drivers or the traffic systems experience. The crash exposure is assumed to have a linear relationship with the logarithm of the mean crash count (log $\mu$): higher exposure is associated with more crashes. Given the crash exposure ($x$), the variation between different observations
(y) is restricted by distribution adapted (Dist(μ)). Put another way, the only stochastic component of variation is introduced by Dist(μ).

In particular, standard Poisson model assumes a fixed variance for different observations given μ, which exactly equals to μ. Hence the variation of y is only determined through observed heterogeneity, i.e. crash exposure in this example. In overdispersed Poisson models, by adding an additional disturbance (ε) to relax the constraint of ‘variance = mean’, the new mean crash count (μ̂) is subject both to the deterministic variation associated with crash exposure but also to the unobserved heterogeneity introduced by ε. For a given crash exposure (x), there is a distribution of μ̂’s rather than a single value for the mean crash count μ. Nevertheless, overdispersed Poisson models only take an overall same distribution on the disturbance among individual observations. Hence different observations are still independent with each other. The potential structural improvement of overdispersed Poisson model over standard Poisson model is only the capability to account for unobserved cross-individual heterogeneity in addition to the observed variations.

However, the “independence” assumption may often not hold true since the multilevel data structures exists extensively, either intrinsically in the traffic data or extrinsically resulting from the manner data are collected or clustered. For example, to study the relationship of crash count and exposure, a number of selected road segments may be nested in several areas of interest (e.g. cities). Moreover, for each selected road segment, there may be several observations from different time periods. In this case, some cross-group heterogeneities, either observed or unobserved, may exist due to spatial and temporal effects of crash data. Indeed, some characteristic variations may necessarily exist between different areas or between road segments.

The within-group correlations could be caused by various group-specific heterogeneities. For those observable heterogeneities, it is theoretically possible to factorize and then account them by using some classical techniques such as GLM with consideration of interactions, ANOVA, or ANOCOVA. But traffic crash is a complex event with a large number of factors involved. Ideally, all of the relevant factors in different levels (e.g. road segment level and area level) should be considered in the model. In practice, however, some of the factors may not be available or even uncollectable for study. A model may only consider the most important factors and omit the others. It assumes that similar groups (i.e. with same selected observable factors) have the same pattern of crash occurrence. In the real world, however, similar groups (e.g. area) may be different in omitted factors and thus may have different means. These unobservable or omitted heterogeneities introduce additional variance to the data and cause the over-dispersion. Consequently, without appropriately accounting for the cross-group heterogeneities, the estimates of the standard error in the regression coefficients may be underestimated. Moreover, in the presence of spatiotemporal correlation, the accommodation of these specific data features would be valued.

The patterns shown in the above example exist almost everywhere in the traffic safety studies since most crash datasets are collected with an inherent multilevel or spatiotemporal structure. For example, in predicting crash severities, it is reasonable to assume that the characteristics of the vehicles within which casualties are traveling will affect their probability of survival. If this is the case, then casualties within the same vehicle would tend to have more similar severity than casualties in different vehicles, rendering the assumption of residual independence invalid. The same argument may be extended to encompass the effect of similarities between different crashes, traffic sites, or geographical regions.
A 5×ST -level Hierarchy in Traffic Safety Data

For the purpose of systematic inspection, a 5×ST -level hierarchy, as shown in Figure 1, is proposed to represent the general framework of multilevel data structures in traffic safety. Along the vertical of this triangular prism is a five-level hierarchy representing various traffic entity with spatial distribution including from macroscopic to the microscopic levels, Geographic region level – Traffic site level – Traffic crash level – Driver-vehicle unit level – Vehicle occupant level. All these traffic entity levels are structured along a horizontal time axis, defined as Time level, thus resulting in a “5×ST” -level hierarchy. The involvement and emphasis for different sub-groups of these levels depend on different research purposes and also rely on the heterogeneity examination on crash data employed. Generally, macro-analysis focus on the top three levels, i.e. Geographic region level, Traffic site level, and Traffic crash level, while micro-analysis concern the bottom three levels, i.e. Traffic crash level, Driver-vehicle unit level, and Vehicle occupant level.

Specifically, the Geographic regional level could be a number of regions, countries, states, counties or cities etc. Inter-regional studies generally include the traffic data collected from the regions of interest. This level are normally associated with a number of contextual factors potentially affecting the traffic safety situation such as driving regulations, road density, spatial features, population and other socio-economic features. Nested under Geographic regional level is Traffic site level, which is of greatest interest in many traffic safety studies. It consists of what constitute the basic road network, namely road segments (link) and road junctions (node). Various collective or comparative safety studies are conducted regarding road design, operation and assessment. Next, while traffic sites necessarily reside in some geographic region, traffic crashes of various types occur at different traffic sites. Traffic crash level has been the most direct and thus most used criterion in monitoring the safety situation for traffic sites. It is intuitively reasonable that characteristics of crashes occurring at a same site should be correlated due to the same context in terms of geometric, traffic, and regulatory control factors. Measures such as crash severity, collision type and possible crash causes are used to characterize the traffic crashes. Driver-vehicle unit level, including driver and vehicle crash involvements, is the most
concerned entity in traffic safety because it directly relates to the life and property loss. Individual severity of driver injury or vehicle damage may potentially show a strong correlation between those involved in the same multi-vehicle crashes. Various driver and vehicle characteristics are factors distinguishing different involved units in this level. The lowest level in the hierarchy is vehicle occupants involved in crashes. This level is commonly concerned with such aspects as driver behavior and vehicle design. Finally, traffic data in any entity level are necessarily marked by a time scale (horizontal axis in the prism), with which the interest of studies may be on the time serial correlations of traffic safety situation.

In the framework of the 5×ST-level hierarchy, typical data-clustering designs in traffic safety research could vary depending on the research purposes. For example, in some inter-regional studies, with Geographic region level as higher level, study subjects in the lower level could be safety performance of various traffic sites, drivers or vehicles. In these cases, two-entity-level design could be used to explicitly examine the safety effects of risk factors in both individual and contextual levels. The two-entity-level design can be naturally extended to reflect three-entity-level data structure, for example, Geographic region level – Traffic site level – Traffic crash level. It is also worth noting that for the levels of geographic region and/or traffic site, spatial effects could be present among adjacent entities of analysis. The geographic distribution of the regions or sites should be taken into account as closer traffic entities may have certain similarity in crash occurrence. Moreover, when time series are considered, panel data design or repeated cross-sectional design could be used. In panel data design, a set of sites within regions are pre-selected on which repeated measures along time are conducted, whereas repeated cross-sectional design consider a number of time periods, in each of which selected sites may be different.

BAYESIAN HIERARCHICAL METHOD ON MULTILEVEL CRASH DATA

Hierarchical Models
Hierarchical modeling is a statistical technique that allows multilevel data structures to be properly specified and estimated (see Gelman and Hill 2007). The hierarchical modeling technique has been gaining an increasing amount of attention in accounting for the multilevel data structure in crash prediction. For example, while some researchers (Shankar et al. 1998; Mitra and Washington 2007; Chin and Quddus 2003; Yang and MacNab 2003; Kim et al. 2007; Li et al. 2008; Quddus 2008; Huang et al. 2009; Haque et al. 2010) employed the hierarchical models for predicting crash frequency, others (Jones and Jorgensen 2003; Lenguerrand et al. 2006; Huang et al. 2008) developed hierarchical models to identify factors affecting crash severity.

As defined by Gelman and Hill (2007), a multilevel/hierarchical model is a regression (a linear or generalized linear model) in which the parameters – the regression coefficients – are given a probability model. Hence, this higher-level model has parameters of its own – the hyperparameters of the model – which are also estimated from the data. In the context of GLM, the hierarchical modeling (also called hierarchical GLMs) is mainly working on the link function: disturbance terms are added to the model corresponding to different sources of variation in the multilevel data.

Specifically, recall the general expression of statistical modeling in Equation (1), while the first part of the expression \( \text{Dist}(\theta) \) remains to represent different characteristics of crash feature of interest, it is the disturbance term \( \varepsilon \) which differs the hierarchical modeling to classical
statistical models. It should be noted that here the \( \varepsilon \) represents a general concept for the disturbances. In fact, it could consist of many components, with some of which working on the intercept, others on the slopes in the link function.

A two-level hierarchical model is used to mathematically interpret how the method works on the multilevel data. As with most practices, a basic linear combination of \( \mathbf{X} \) and \( \mathbf{\beta} \) is assumed to simplify the interpretation. Furthermore, the covariate vector \( \mathbf{X} \) is divided into three components, \( \mathbf{X}^{(1)}, \mathbf{X}^{(2)} \), to respectively represent the factors associated with intercept, individual level (level 1) and group level (level 2). Correspondingly, \( \mathbf{\beta} \) and \( \varepsilon \) are also divided into different components to serve different functions with the bold symbol representing vector or matrix. Hence, the link function becomes the combination of models in terms of two levels,

\[
\begin{align*}
\text{Level 1 model:} & \quad f^{-1}(\mathbf{\theta}) = \beta_0^{(1)} + \mathbf{X}^{(1)} \beta^{(1)} + \varepsilon^{(1)} \\
\text{Level 2 model:} & \quad \beta_0^{(2)} = \beta_{00}^{(2)} + \mathbf{X}^{(2)} \beta_0^{(2)} + \varepsilon_0^{(2)} \\
& \quad \beta^{(2)} = \beta_{01}^{(2)} + \mathbf{X}^{(2)} \beta_1^{(2)} + \varepsilon_1^{(2)}
\end{align*}
\]

The combined model is obtained by substituting the Level 2 model into Level 1 model,

\[
f^{-1}(\mathbf{\theta}) = (\beta_{00}^{(2)} + \mathbf{X}^{(1)} \beta_{01}^{(2)} + \mathbf{X}^{(2)} \beta_0^{(2)} + \mathbf{X}^{(1)} \mathbf{X}^{(2)} \beta_1^{(2)}) + (\varepsilon_1^{(1)} + \varepsilon_0^{(2)} + \mathbf{X}^{(1)} \varepsilon_1^{(2)})
\] (3)

It is clear that now the link function consists of two parts: fixed part and random part. The fixed part means a deterministic relationship fully depending on covariate \( \mathbf{X} \), while random part is stochastically determined by a number of disturbance terms. The components in both the two parts are interpreted as follows,

**Fixed part:**

1) \( \beta_0^{(1)} \): The intercept, which is the main effect with all covariates equal zero. By centering all covariates on their mean, this term represents the main effect on the average values of covariates.

2) \( \beta_0^{(2)} \): \( \beta_0^{(2)} \) is the mean of the main-effect coefficient of level 1 covariates \( \mathbf{X}^{(1)} \) on the dependent variable.

3) \( \mathbf{X}^{(2)} \beta_0^{(2)} \): \( \beta_0^{(2)} \) is the main-effect coefficient of level 2 covariates \( \mathbf{X}^{(2)} \) on the dependent variable.

4) \( \mathbf{X}^{(1)} \mathbf{X}^{(2)} \beta_1^{(2)} \): \( \beta_1^{(2)} \) is the interactive-effect coefficient of \( \mathbf{X}^{(1)} \) and \( \mathbf{X}^{(2)} \). This component make it possible to in-depth understand how contextual factor (level 2 covariates) could affect the individual factor (level 1 covariates).

**Random part:**

1) \( \varepsilon_1^{(1)} \): The disturbance term associated with level 1 analysis. Normally, it is assumed to be identical independent distributed (IID) among individuals with mean zero and variance to be estimated. The associated unknown variance structure of this term facilitates the estimation of unobservable or omitted between-individual heterogeneity. The additional disturbance in overdispersed Poisson models is a typical example, in which with Gamma distribution assumption on \( \exp(\varepsilon) \) resulting in Poisson-Gamma model, and Lognormal distribution assumption in Poisson-Lognormal model.
2) \( \varepsilon_0^{L2} \): The disturbance term associated with level 2 analysis. It is also common to assume IID among groups (level 2) with mean zero and variance to be estimated. With this term, those individuals (level 1) belonging to a same group (level 2) share a same variance component, thus resulting in a within-group covariance. As a result, the model intercept now consists of three parts: \( \beta_{00} + \varepsilon_0^{L1} + \varepsilon_0^{L2} \) and is hence variable by between-individual (or within-group) variation \( \varepsilon^{L1} \) as well as between-group variation \( \varepsilon_0^{L2} \).

3) \( \mathbf{X}^{L1} \varepsilon^{L2} \): \( \varepsilon^{L2} \) is the disturbance vector on the slope of level 1 covariates \( \mathbf{X}^{L1} \) associated with level 2. \( \varepsilon^{L2} \) makes the slope of \( \mathbf{X}^{L1} \) variable according to the data clustering. In other words, individuals in a same group share with a same variance on the slope. As a result, the slope of \( \mathbf{X}^{L1} \) consists of two parts: \( \beta_{01}^{L2} + \varepsilon_{1}^{L2} \) and is hence variable by between-group variation \( \varepsilon_{1}^{L2} \). Note that while \( \mathbf{X}^{L1} \) has varying main-effect slope, the main-effect slope for \( \mathbf{X}^{L2} \) is fixed. A higher level analysis, for example in a three-level model, could make this level 2 slope varying.

It is clear that \( \varepsilon_0^{L2} \) and \( \varepsilon_1^{L2} \) are the unique features of hierarchical models while all of the rest components could be included and estimated in classical models. It is just these two stochastic terms making it possible to account for the unobservable or omitted heterogeneity in Level 2 model.

In the framework of hierarchical modeling, the two-level model shown in Equation (3) is also called as varying-intercept and varying-slope model as defined by Gelman and Hill (2007). Obviously, this full-version model could be simplified by taking account of either varying intercept or varying slope, resulting in varying-intercept model and varying-slope model.

Varying-intercept model:
\[
f^{-1}(\theta) = (\beta_{00}^{L2} + \mathbf{X}^{L1} \beta_{01}^{L2} + \mathbf{X}^{L2} \beta_0^{L2} + \mathbf{X}^{L1} \mathbf{X}^{L2} \beta_{11}^{L2}) + (\varepsilon_0^{L1} + \varepsilon_0^{L2})
\]

Varying-slope model:
\[
f^{-1}(\theta) = (\beta_{01}^{L2} + \mathbf{X}^{L1} \beta_{01}^{L2} + \mathbf{X}^{L2} \beta_0^{L2} + \mathbf{X}^{L1} \mathbf{X}^{L2} \beta_1^{L2}) + (\varepsilon_1^{L1} + \varepsilon_1^{L2})
\]

Clearly, all these models could be expanded to accord with more complicated designs. The above derivative also shows that the hierarchical modeling provides a rather flexible technique to account for various study purposes and different extent of model complexity such as within-level or between-level interactions, varying intercept, and varying slopes. Moreover, spatiotemporal effects could also be incorporated into the hierarchical models by specifying the hypothesized features on the \( \varepsilon_0^{L2} \) and \( \varepsilon_1^{L2} \), such as spatial or temporal autoregressive models (see Banerjee et al. 2003).

**Bayesian Inference**

With the recent development of computing capacity and Bayesian analysis techniques, a good number of researchers have been working on calculating the models in a Bayesian framework. Bayesian inference (BI) is the process of fitting a probability model to a set of data and summarizing the result by a probability distribution on the parameters of the model and on unobserved quantities such as predictions for new observations. Instead of giving “maximum likelihood” estimates for the studied unknowns totally based on the sample data in MLE inference, the essential characteristic of Bayesian methods is its explicit use of probability for
quantifying uncertainty in inferences based on statistical data analysis. Specifically, the ultimate aim of Bayesian data analysis is to obtain the marginal posterior distribution of all unknowns, and then integrate this distribution over the unknowns that are not of immediate interest to obtain the desired marginal distribution. The BI is recommended for the proposed hierarchical models. As indicated from a large number of theoretical studies and applications, BI shows numerous theoretical and practical advantages over the “classical” likelihood-based inference methods (also called frequentist methods).

The general computing approach for BI is Markov chain Monte Carlo (MCMC) methods (Gelman et al. 2003). MCMC is a general method based on drawing values of unknowns from approximate distributions and then correcting those draws to better approximate the target posterior distribution. Gibbs sampler and the Metropolis-Hastings algorithm are the most widely used simulation algorithms in MCMC. In complex hierarchical models where parameters may outnumber observations, the recently-developed Deviance Information Criterion (DIC), a Bayesian generalization of AIC, could be used to measure the model complexity and fit (Speigelhalter et al. 2003a). Galman-Rubin convergence statistics (Brooks and Gelman 1998) could be employed to monitor the convergence of MCMC simulation chains. BUGS modeling language (Bayesian Inference using Gibbs Sampling) is a prevailed tool to allow the computation using MCMC algorithms for all sorts of Bayesian models, including most of the hierarchical models applied. WinBUGS package (Spiegelhalter et al. 2003b) provides a flexible and simplified platform to modeling with the BUGS programs. In particular, since specification of the full conditional densities is not necessary in WinBUGS, small changes in program code can achieve a wide variation in modeling options and thus facilitating sensitivity analysis and prior assumptions.

ILLUSTRATIVE EXAMPLES

In this section, three studies recently accomplished by the current authors and their colleagues are summarized to exemplify the proposed conceptual model of the 5×ST -level hierarchy with Bayesian hierarchical estimation approach.

Example 1: Crash frequency ~ Intersection level × Time level
To evaluate alternative approaches in identifying crash hotspots, Huang et al. (2009) developed a set of Bayesian hierarchical models to predict the expected crash rate for 582 intersections in Singapore, which were subsequently used to rank those sites for determination of safety investment priority. Crash historical data in ten years (1997-2006) were employed to accomplish the analysis. Specifically, a two-level design was employed to accommodate the site-specific effect for multiple yearly observations for specific sites, i.e. Crash frequency ~ Intersection level × Time level. The potential correlation among multiple observations at a specific site was modeled in two ways, one with a site-specific random effect, and the other with a time serial autoregressive lag-1 (AR-1) specification.

Table 1 cites the model comparison results presented in Huang et al 2009. The results showed that both the hierarchical models (Hierarchical Poisson model, HP and Hierarchical Poisson (AR-1) model, HP(AR-1)) with accommodation for site-specific effect and serial correlation have better goodness-of-fit than non-hierarchical models (NB model and Poisson-Lognormal model, PLN). Specifically, judged by the MAD and MSPE values, the HP and
HP(AR-1) models significantly outperform NB and PLN models with respect to model-fitting. Likewise, by using DIC, the model comparison shows that the accommodation of multilevel data structure can substantially improve the model performance. Given the better modeling results, it is also not surprising to find that the Bayesian hierarchical models outperform the results based on traditional crash prediction models in correctly identifying crash hotspots (see Huang et al. 2009 for details). It indicates that the flexibility in model specification of Bayesian modeling approach can generate great potentials to improve the crash prediction models and subsequent applications by explicitly accounting for various structured heterogeneities in crash data.

Table 1 Model comparison: hierarchical model vs. GLM model

<table>
<thead>
<tr>
<th></th>
<th>Deviance information criterion (DIC)</th>
<th>Mean absolute deviance (MAD)</th>
<th>Mean squared predictive error (MSPE)</th>
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</thead>
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<tr>
<td>Negative Binomial</td>
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<tr>
<td>Poisson-Lognormal</td>
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<tr>
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<tr>
<td>Hierarchical Poisson (AR-1)*</td>
<td>7339</td>
<td>0.51</td>
<td>1.03</td>
</tr>
</tbody>
</table>

* serial correlation coefficient = 0.775, Bayesian credible interval (0.72, 0.80)
Note: results retrieved from Table 1 in Huang et al. 2009.

Example 2: Crash frequency ~ County level × Spatial effect

The necessity and capability of spatial model to account for spatial data as shown in Example 2 has also been explored in an aggregate crash prediction model (Huang et al. 2010). In the study, crash statistics in a five-year period (2003-2007) were investigated for 67 Florida counties. By using the Moran’s I statistics in GIS platform, positive spatial correlation was detected among adjacent counties with most of the Z scores higher than 1.68 which represents a 90% confidence level. Hence, a Bayesian area-referenced CAR model was developed to accommodate the potential spatial effects. The spatial model was assumed to be able to account for various confounding factors which are not observed or unobservable in the analysis. Furthermore, in the context of area-referenced CAR model, those confounding factors are supposed to be spatially correlated among adjacent counties and their effects on crash risks are homogeneous. Estimations of the marginal standard deviations of state-wide heterogeneity and clustering effects among adjacent counties were used to calculate the proportion of the variability in the random effects that is due to clustering. The results showed that variations accounted by spatial clustering are substantial for all the all-crash and severe-crash risk models, specifically, 51.7% and 42.4% for models controlled by daily VMT and 25.9% and 26.4% for models given population.

Example 3: Severity of driver injury and vehicle damage ~ Traffic crash level – Driver-vehicle unit level

The Examples 1-2 have illustrated the application of Bayesian hierarchical models in addressing crash frequency prediction models with multilevel and spatiotemporal data structure. Example 4 and 5 will exemplify how to deal with multilevel data in crash severity analysis.

In Huang et al. (2008), a Bayesian hierarchical binomial logistic model was developed to identify the significant factors affecting the severity level of driver injury and vehicle damage in traffic crashes at signalized intersections. Crash data in Singapore from 2003-2005 were used. It was found that in the 4095 signalized intersection related crashes, 7840 driver-vehicle units were involved, resulting in an average involvement rate of 1.91 individuals per crash. A preliminary inspection on the crash severity of these data revealed a significant correlation between...
individuals involved in same multi-vehicle crashes, which represent 83.5% of all crashes. Specifically, in a multi-vehicle crash, if a driver and/or vehicle was injured and/or damaged severely, then the others had a probability of 31% also to be so. One the other hand, if there was no severe damage and injury to a driver-vehicle unit, the chance for the others to be severe is only 12%. This induced a two-level hierarchical design of the model, i.e. Crash Severity ~ Traffic crash level – Driver-vehicle level, so as to take into account the potential cross-crash heterogeneity. For the purpose of comparison, standard logistic model has also been developed to justify the use of the more ‘expensive’ two-level model.

Model estimation results showed that the variance of the crash-specific random effects is 1.34, which is statistically significant. By use of intra-class correlation coefficient (ICC), this means the proportion of unexplained variations in individual severity resulted from cross-crash variance is about 28.9%. Thus, it is not surprising to hypothesize that accounting for the multilevel data structure in the proposed hierarchical model would lead to a better model performance. By the model-fitting component in DIC, the goodness-of-fit of the proposed two-level model improved significantly over the standard logistic model in which all driver-vehicle units were treated independently. After penalized by the effective number of parameters in the model, the DIC value for the hierarchical model (3067.9) is also hugely less than that in the standard logistic model (6191.9). This further showed that the use of crash-level random effects in the hierarchical model can substantially improve the model performance.

A FURTHER NOTE ON THE APPLICATION ISSUE

A number of recent studies, including those by current authors, have shown the usefulness of accounting for specific safety data structure by using Bayesian hierarchical models. A revolutionary improvement is promising to traffic safety practice in near future by promoting and appropriately applying this emerging approach. Towards this end, the current paper attempted to regularize various safety data structures and the corresponding analytical approach related to the development of crash prediction model or safety performance function. The proposed 5×ST-level hierarchy represents a conceptual framework with all up-to-date understandings on safety data structure. The state-of-the-art technology, i.e. Bayesian hierarchical approach, has shown good potential to theoretically account for the specific multilevel data structure as indicated in the 5×ST-level hierarchy.

Although a lot of successes have been reported in literature, there is still a substantial distance to the wide application of the proposed theory and method in traffic industry. The first issue in need of future effort is the reliability test of the hierarchical models in yielding better results in traffic safety. Although these types of model have been well-coordinated in many other fields such as economics and sociology, it is only less than ten years when traffic safety analysts first reported relevant results in well-known publications. Much more effects are thus needed to test the reliability, applicability, robustness and transplantability of these emerging technologies. Another issue related to application concerns the cost-benefit rate. The current methods available in calibrating hierarchical models especially in a context of Bayesian approach, are relatively computing and intellectual intensive. The costs for applying those technologies to industry should be carefully evaluated by comparing to benefit estimation toward possible life and property savings.
REFERENCES


Contents session 6  Crash Recording Systems and Safety Auditing I

Evaluation of road Traffic Accidents in Germany – Need of Data and analysis
Sabine Degener, Unfallforschung der Versicherer, Germany

Road Crash and Victim Information System (RCVIS)
Sem Panhavuth, Handicap International Belgium, Cambodia

A Data Quality Case Study for Turkish Highway Accident Data Sets
Omur Kaygisiz, General Directorate of Security, Traffic Research Center, Turkey

Assessment of Crash Database System of the United Arab Emirates
Md. Bayzid Khan, United Arab Emirates University, United Arab Emirates

Characteristics of Injury Crashes in Dubai, UAE
Mostapha Al-Dah, ESRI, Loughborough University, UK
ABSTRACT
The accident situation on streets of Europe is very high furthermore. In 2007 42,453 people died on the EU27 roads. In Germany the number of killed person on the streets is still 4,949. The aim that the EU gives itself in the white paper in 2001 (halve the number of the traffic dead person till 2010) has not been reached.

In 2010 important points are put for the road safety work. The European committee has initiated with different events the Stakeholder process for the Road Safety action programmes 2011 - 2020. The Federal Government in Germany also wants to provide a new road safety programme. To promote best practise into that process Germany could give a successful example: "the method of accident investigation", that is suitable to the imitation internationally. Accidents do not only result from mistakes made by humans using the road – they can also be caused by factors such as faults in the road environment (e.g. narrow bend, missing safety barrier, etc.). Many of those faults have no repercussions because of the “safety allowance” inherent in the road-traffic system. That “allowance” comes into play when weather, road or traffic conditions are poor or when a vehicle is poorly equipped. However, if several of these risk factors occur at once (e.g. night time, rain, poor road markings and worn tyres), a moment’s inattentiveness is often enough to cause an accident. Consequently, accidents are often found to be due to a combination of several causes, not one single cause.

The special about frequent accident sites (FAS) is the prevalence of local contributing factors. These factors arise from aspects such as faults in alignment, intersection layouts, signing, road markings or traffic devices. If one accident-inducing factor in the road environment can be isolated, described and then remedied, the “safety allowance” at that site will increase. The result will be fewer and/or less severe accidents. So a large number of causes doesn’t mean a large number of measures is required. Since several factors at the site in question could have an accident-inducing effect, several measures may be suitable but only one of them needs to be selected.

It is the Accident Committees’ task to devote their efforts to eliminating FAS. Part of this work is also to make the importance of their work clear to others. The German government has required locally based accident committees since 1971. More than 500 of these city- and county-committees exist, and they are required to meet at least twice a year. The multidisciplinary committee typically are composed of seven or eight members or including police officers and representatives of the road construction sector and the traffic authorities. The legislative requirement to have these committees has in formalized and made commonplace the process of multidisciplinary local safety analysis in Germany. Accident Committees are one important part of a network road safety management.
1 INTRODUCTION

The accidents on German roads still claims too many victims, although the number of fatalities and injuries in the last 40 years has been significantly reduced. 4,477 persons were killed and 409,047 persons were injured on Germany’s roads in 2008. Hence the positive trend of the last few years continued in 2008 for the number of persons killed in traffic accidents. The number of persons killed was the lowest since 1950. Nevertheless, no less than an average 12 persons per day were killed in road traffic accidents in 2008. The first overall result for Germany (based on today’s territory) can be calculated for 1953: 12,631 people were killed in traffic accidents, while the number of vehicles amounted to nearly 4.8 million. Both figures increased over the subsequent years: In 1970, 21,332 fatal casualties were counted in road traffic and the number of road motor vehicles increased to 20.8 million. Except for very few years, the number of persons killed in traffic has steadily declined since then, although the stock of vehicles has further increased.

The main causes recorded for accidents involving personal injury in 2008 were mistakes in turning off, turning, reversing, entering and starting. The second most common cause of accident was cutting off someone’s right of way or ignoring priority. For the first time, inappropriate speed was just the third most frequent cause of accident in 2008. Especially for serious accidents, the influence of alcohol plays a major role, too. That cause of accident declined slightly by 5.5% compared with 2007.

Figure 1: Trend in the number of persons killed in road traffic accidents in Germany

In 2001 the European Union brought out its “White Paper” which should force on the member states to reduce the number of person killed in road traffic accidents on their roads about the halve. Nevertheless, this aim has failed.
In order to stabilize and reinforce the trend to continue if possible, there is still an urgent need for action. Requirement for a specific calamity are good data bases and corresponding organizational forms.

2 ROAD – A SIGNIFICANT FACTOR IN SAFETY SYSTEM

The general consensus among road safety experts is that the human element is the key causal factor related to road accidents and their consequences. Of course, drivers basically determine the movement of the vehicle on the road, and must adapt their behaviour to existing traffic regulations, and to the road surface, traffic, and weather conditions in accordance with their driving skill and relative health status. We know human behaviour is influenced by myriad elements related to its individual features and abilities, skills and experience, current physical and psychical state, and perception of the actual traffic and road conditions.

But many spots or stretches of road that have similar features show a high frequency of accidents. This means that the actual location of the road instigates inappropriate driver responses, or provides misleading stimuli to driver perception that creates confusion and/or delayed reactions. To identify and examine these locations and to characterize the safety deficiencies is the challenge for road engineers. The mere appearance of a repetition of accidents with similar features offers an excellent guide as to where to apply improvement measures.

3 NEED OF DATA

Accident data is the crucial element for road safety intervention. But it is not only a description of the accident circumstances that are needed. Contributing factors like road and traffic characteristics, vehicle parameters, and information about the people involved has to be registered as well.

A basic set of data to provide road engineers with relevant information necessary for basic accident investigation can be identified as follows: accident identification, (unique system-based number), time (date, hour, and minute), location, accident type, vehicles involved (number, type) and accident consequences (fatalities, injuries within 24 hours/30days, material damage).
This key information will enable the basic evaluation of the level of a road’s safety in comparison with others. This information can direct a road engineer to certain locations which show a higher accident frequency, and provide with a basic outline of the possible circumstances that may have led to an accident. With the aid of additional parameters and features relative to the accident site, an estimation of potential deficiencies of road infrastructure can be determined and elaborated. Certain locations may offer an obvious link between accident causation and the failure of a road or its surroundings.

The next level can be developed in such a way that will provide road engineers with relevant road infrastructure information linked with the site of the accident and other circumstances contributing to the accident occurrence. Even in this case, a complementary site investigation is desirable and can formulate some open questions.

A complete set of information enables a more detailed and precise investigation that excludes the seeming appearance of the typical single human or vehicle based failure (e.g. breakdown of vehicle, alcohol or drug impairment...)

4 ACCIDENT TYPES
An assignment of individual accidents according to their common features into several groups facilitates and defines the investigation process. Therefore, groups of accidents according to their occurrence and the type of collision were identified as follows (figure3):

![Figure 3: Accident types in Germany](image)

These basic groups are subsequently divided according to the conflict position of the vehicle(-s). Cumulated road accidents of the same or similar type at a certain site on road network may have the same or a similar cause. When asking the question of what makes drivers take risks or make mistakes at such road sites, negative effects of roads may be discovered. Poor road geometry, e.g. characterised by optical and psychological illusions, may significantly affect the road accident rate.

5 ACCIDENT DIAGRAM
Collision diagrams are very simple and efficient tools for road accident analysis. They allow to obtain an overview of major characteristics of individual road accidents in a short time. Collision diagrams are made to display important road accident patterns with symbols (arrows and other symbols) in (or next to) a traffic scheme (figure 4).
Collision diagrams allow to get a broader idea of road accident rate on a particular spot without extensive text comments. To choose right counter-measures it is important that they clearly display the same patterns of road accidents. Besides clearly displayed road accidents in the given period in order to carry out their analysis, collision diagrams are also suitable for comparisons of road accident rate before and after (accident per year and kilometre).

Accident diagrams illustrate whether a disproportionately high number of vehicles from certain directions are involved in the accidents at black spots or whether certain factors have played a role in the accidents (e.g. pedestrians crossing between parked vehicles).

Accident diagrams should be drawn in such a way that the special features of the site and the accident can be seen at a glance (figure 5).

Figure 5: Example of an accident diagram for a curve at which traffic from the right has run into trees is a striking concentration of accidents involving vehicles coming from one particular road site.
6 REPORTING BLACK SPOTS TO THE ACCIDENT COMMITTEES

Activities to combat road-traffic accidents as specified in the Administrative Regulation concerning Section 44 of the “StVO” Road Traffic Regulations have to be performed by the police and the road-traffic and road-construction authorities in close cooperation. That cooperation usually takes place in the “Accident Committees”, whose structures and responsibilities are set out in orders issued by the federal states. Representatives of the above-mentioned authorities serve as permanent members in the Accident Committees.

The purpose of the Accident Committees’ meetings is to explain the findings of the investigations in detail, to determine the required improvement schemes on the basis of those findings, adopt such measures formally and issue instructions for their implementation. Consequently, the documents supplied for an Accident Committee’s meeting should provide data which is as meaningful as possible. Apart from the agenda (the meeting documents should include the following for each black spot to be reviewed):

- black spot report to the Accident Committee
- accident occurrence summary
- accident list,
- accident diagram,
- extract from the map (if the accident-type map is not present at the Accident Committee’s meeting),
- Long-term conversion
- tabular summary (or summaries) of accident occurrences
- and any striking special features,
- the temporal-development assessment for mass-occurrence
- spots and
descriptions of striking common features and accident-inducing factors (“contributing factors”).

When drawing up reports to Accident Committees, it is recommended that a brief explanation of the striking accident features determined to date be provided. This enables guidance to be given to Accident Committee members during accident-site inspections.

7 ACCIDENT-SITE INSPECTIONS

Accident-site inspections provide background information for the decisions to be made at Accident Committee meetings. The aim of such inspections is to see first-hand the effects which the site and the traffic flow have on accident occurrence. They also serve as a means of determining whether the striking accident features (common features, common features of pre-accident road users’ driving directions, etc.) are in part due to shortcomings which could be changed. (Examples of such shortcomings would be: high hedges obstructing road users’ views in the case of “turning into/crossing accidents”; poor planning of cycle routes in the case of black spots involving cyclists; poor skid resistance/road surface or failure to give sufficient advance indication of a bend in the case of accidents on bends; etc.). Thus, the point of such inspections is to identify contributing factors at the accident site based on the preceding accident analysis, to gather additional information on them and to substantiate that information or to put forward suggestions for further investigation (e.g. speed measurements if there are grounds to believe that vehicles are travelling at inappropriately high speeds). If a large number of accidents happened in the dark, these accident-site inspections should also be carried out in the dark. If the accident-site inspections conducted by individual Accident Committee members have resulted in conflicting impressions, a joint inspection should always be carried out. The Code of Practice for Evaluation of Road Traffic Accidents, Part 2 “Measures against frequent accident sites” gives a detailed explanation of how the accident-investigation
findings and the results of accident-site inspections can be used to determine the factors which contributed to the accidents.

8 ACCIDENT COMMITTEES’ PROCEDURE FOR IDENTIFYING SCHEMES
The local accident investigation results in one or several proposals for promising schemes with which to remedy the black spot under examination. The different proposals are discussed by the Accident Committee concerned and should be adopted by mutual agreement. A distinction is drawn between immediate-action measures and more extensive (construction) schemes which are generally additionally necessary for frequent-accident spots (FAS), frequent-accident lines (FAL) or frequent-accident areas (FAA) with mostly fatality and serious injuries if secondary construction schemes are to be carried out at black spots. To ensure that the Accident Committee can concentrate on the real objective of local accident investigation, it is recommended that Accident Committee meetings follow an agenda of the type shown here. The accident-type maps should always be on view at Accident Committee meetings.

9 MONITORING
Even if a beneficial improvement scheme has been identified, it cannot have any effect until it is implemented. So it is important to secure financing in plenty of time and to monitor the implementation of the schemes decided on.

To this end, it is recommended that the status of each black spot be indicated on the accident-type maps as well as the month and year in which the related schemes were adopted. When new maps are started, the symbols on the old maps should immediately be transferred to the empty map in order to ensure ongoing monitoring. One a year, a special meeting should take place to analyse accident occurrence in the region for which that particular Accident Committee is responsible. The heads of the relevant authorities (the police, road-construction authorities and road-traffic authorities) should be invited as well as, if necessary, representatives of the relevant municipal and regional councils. In particular, where no scheme is implemented to remedy identified black spots, a separate report should be sent to the supervisory authority, advising it of the reasons why action was not possible.

10 EFFECTIVENESS MEASUREMENT
Effectiveness measurement (by means of a before & after comparison) is always necessary when there is doubt concerning how a scheme will work or no widely available proof of its effectiveness. It is also advisable if examples of good practice are to be presented as “models” for other problem areas. The “before” part of an effectiveness measurement is covered by the local accident investigation. The process for the second part, the “after” part, is similar to that for the “before” part. The following points must be borne in mind: the before and after periods must be the same in terms of number of months and which months are included; the impact zone of the black spot ascertained in the preliminary investigation must be copied precisely in the “after” part; and the scheme-implementation period must not be in one of the observation periods. Thus, the effectiveness-measuring process must be interrupted for the duration of the scheme’s implementation. The implementation period should also be extended to include an adaptation period for road users, which should last one to three months depending on the extent of the modifications made. If there have been only slight changes in accident occurrence, the modification at the black spot should be compared with those at similar sites. If the effectiveness-measuring process indicates that the scheme implemented has not been successful, the black spot needs to be re-examined and additional or substitute schemes proposed and implemented.
11 EXAMPLE: WORK OF ACCIDENT COMMITTEES’ IN GERMANY

Accidents do not only result from mistakes made by humans using the road – they can also be caused by factors such as faults in the road environment (e.g. narrow bend, missing safety barrier, etc.). Many of those faults have no repercussions because of the “safety allowance” inherent in the road-traffic system. That “allowance” comes into play when weather, road or traffic conditions are poor or when a vehicle is poorly equipped. However, if several of these risk factors occur at once (e.g. night time, rain, poor road markings and worn tyres), a moment’s inattentiveness is often enough to cause an accident.

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The German government has required locally based accident committees since 1971. More than 500 of these city- and county-committees exist, and they are required to meet at least twice a year.

The multidisciplinary committee typically are composed of seven or eight members or including police officers and representatives of the road construction sector and the traffic authorities. The legislative requirement to have these committees has in formalized and made commonplace the process of multidisciplinary local safety analysis in Germany.

In Germany the police is collecting the accident database of all accidents gets to their knowledge. The police prepare accident type maps (pin maps) for the previous year and the proceeding three years. The one year map includes all crashes, that have occurred at each location and the three year map includes only those fatalities or serious injuries. About the third of the localities also review collision diagrams prepared by the highway agency.

12 METHODS OF ACCIDENT INVESTIGATIONS:

The committees maybe one reason, a high level of safety coordination and communication occurs throughout the country. The local accident committees are required to identify, investigate and suggest solution for high-risk black-spot location within their in jurisdiction. They review pin maps, which are documents with coloured pins to indicate location of crashes of various types and severity levels.

The suggested criteria for identifying a safety black spot in a German locality is five similar crashes at a location in the past year, three fatalities or serious injuries in the past three years, or five personal injuries-crashes within the past three years (figure 6). Committees typically know where black spot locations are in their locality and may consider all location with five or more crashes in the year. They identify the twenty to thirty locations that cause the most concern, with a focus on location with recent fatalities and crashes involving children.
Many accident committees are lacking the proven knowledge about measures which maybe effectively used to combat the safety deficiencies at frequent accident sites. Therefore many poor decisions are made. A guideline "Code of Practice for Evaluation of Road Traffic Accidents Part 1, “Managing and Evaluating Accident-Type Maps” and “Part 2. “Measures against Frequent accident sites” has been is published. Part 2 was developed by the German Insurers Accident Research (UDV) in consultation with accident committees, measures are described which will ensure effective improvement on the roads in both urban and rural areas. In addition, suggestions of investments, financing help and other appropriate measures are given (figure 7).

Figure 6: Limit values for frequent-accident spots (FAS)

<table>
<thead>
<tr>
<th>Accident-type map</th>
<th>Limit value</th>
<th>Observation period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Year map</td>
<td>5 (of comparable nature)*</td>
<td>12 months</td>
</tr>
<tr>
<td>3-Year map (I)</td>
<td>5</td>
<td>36</td>
</tr>
<tr>
<td>3-Year map (SI)</td>
<td>3</td>
<td>36</td>
</tr>
</tbody>
</table>

* If accidents involving offences for which a caution can be given are not included on the one-year map, the limit value decreases to four comparable accidents in twelve months.

Figure 7: Scheme of accident committee work
Crash analysis in Germany is also done in a larger scale and at different stages of a roadway improvement.

In Germany the government of the federal states offer - in collaboration with the German Insurance Association (GDV) - a significant amount of safety training and technology transfer. For example, police officers, including those at the local accident committees receive consistent and comprehensive training in the areas of traffic management and crash analyses at the federal police leadership academy. They are trained in developing pin maps, as well as in analysing and evaluating traffic safety situation. For this reason they are participants in accident committee discussions. Their training and the data they provide make them essential and knowledgeable committee members.

Some accident committees, of course, are more effective than others. A training program for committees has been developed by the German Insurers Accident Research (UDV) and instructors have been being trained. These documents are available to the accident committees. These documents help committees with their use of pin maps and provide examples and photos for possible county measures for black spot locations. But this new information is generated only because of research and consultation practice and it is allowing a more efficient Accident Committee's work.

German Insurers accident Research (UDV) triggered this process with a research study of the particular importance of accident committees in 1998. (Mitteilung 37: „Unfallkommission von innen”) Through a nationwide action UDV have been questioning the framework of cooperation in the accident committees at various levels (policy, - country and district, county and municipal level, and the level of accident committees). Particular emphasis was placed on the analysis of vulnerabilities, because only such detailed approaches could be identified for improvement.

The study conducted by German Insurers Accident Research has revealed that the deficits were essentially associated with four decisive factors:

- insufficient qualification of the members of Accident Committees,
- lack of information on road-safety-related facts and in-house planning projects of the authorities, etc.,
- little decision-making authority of staff members of Accident Committees and
- formal harmony (no constructive critical working within the body).

The analysis of everyday practice has shown that the body of “Accident Committee” was in-existent at that time. Although cooperation between the police, the road construction authority and the road traffic authority was laid down even in those days, staff members did not regard themselves as a team because they belonged to different authorities. Moreover, in most Federal State ordinances, the sphere of action was not precisely laid down, which was an essential reason for the fact that many Accident Committees almost exclusively decided upon urgent measures providing for simple means, such as signposting and markings, although accumulations of serious accidents may often only be eased effectively through more comprehensive measures.

Despite these mainly structural shortcomings, even in those days, it had to be pointed out that many Accident Committees did a good job given the existing framework conditions and that many contacts could rightly feel satisfied with their success. It is worthy of note what has been achieved by individual Accident Committees despite lack of support, little scope, etc. This was and, for the most part, still is due to the personal commitment of staff members.

These findings were discussed in 1998 in cooperation with the German Road Safety Council (DVR) in information meetings held jointly with high and supreme authorities of the Federal States and the former Police Academy ( now German Police University ), with the aim of in-
tegrating these innovations in the form of model meetings into advanced training courses for Accident Committees in the Federal States. At these meetings, in which almost all 16 Federal States participated, the new findings were basically confirmed or approved. In this context, it became apparent that those Federal States which had introduced the 3-year accident type map, either bindingly or on a recommendatory basis (more recent ordinance),

- have an (active) Accident Committee of the Federal State at their disposal or/and
- are engaged in active accident evaluation,

were able to report on special achievements in practice.

Also, it became apparent that in practice controlling in the form of help and supervision from above already partly existed. Moreover, it had emerged that in some Federal States the building authorities were working with a more up-to-date state of knowledge than required by the ordinances on local accident analysis. In addition, it was emphasized that for instance in Bavaria and Rhineland-Palatinate it had been possible to sensitize politicians and citizens to the concerns of the Accident Committee better than before by means of the 3-year map.

The Federal States of Saxony and Lower Saxony had already reacted to new findings and drafted or prepared new ordinances in 1996.

From the discussion with the Federal States the following proposals were very much appreciated:

1) Introduction of the following measures through appropriate ordinances

- Keeping 1-year accident type maps on all accidents and 3-year accident type maps on accidents involving severe bodily injury or bodily injury
- Evaluation on the basis of simplified limits, hence increased consideration of accident severity
- Introduce the name “Accident Committee” to refer to the body in charge of local accident analysis
- Setting-up an Accident Committee of the Federal State and, where appropriate, a District Accident Committee and possibly a central accident evaluation agency to improve controlling

2) Ensuring financing

- Setting priorities for measures against accident accumulations in households, improving information on financing possibilities
- Own budgetary items “Elimination of accident accumulations” in the administrative budgets of districts and municipalities

3) Public relations

- Seminars for politicians or mayors or Road Safety Days with an emphasis on the Accident Committee
- Annual Meeting of the Accident Committee with press conference
- Highlight the positive aspects of measures against accident accumulations also through the media

4) Initial and further training

- Training of trainers by German Insurers Accident Research (UDV)
- Curriculum (syllabus)
- Qualification for the activity in the Accident Committee
- Further training and exchange of experience of trainers and members.

The information meeting had been very well received. Thereupon, a national project group had drafted the curriculum for the contents of initial and further training for the Accident Committee in 1998/1999. Subsequently, according to this curriculum, multipliers were trained by German Insurers Accident Research for the Accident Committees’ own initial and further training in the Federal States. Thus, it was ensured that the qualification of staff members
working in the Accident Committees was enshrined. In multi-day seminars both new and experienced members of Accident Committees from the authorities involved in many Federal States received and still receive the required basic knowledge.

Meanwhile, more than 180 lecturers from the Federal States have been acquainted with the overall materials on the Accident Committee. In addition, UDV has initiated and organized exchanges of experience jointly with DVR to ensure the possibility for lecturers to participate in the experience gathered by other lecturers beyond the borders of their respective Federal States. In the course of these exchanges of experience it has become apparent that despite all the achievements made over the last few years the significance of the Accident Committee, even today, depends very much on persons. As soon as certain changes in the staff of offices, also of ministries, occur, there may be serious setbacks as regards the significance of the Accident Committee. However, if a streamlined structure is established around the Accident Committee, this may lead to great achievements made by the Accident Committee also within a legal framework or by way of ordinances.

On the other hand practical research was needed to improve the criteria of frequent accident sites: the today's criteria (1JK: 5 accidents of the same kind; 3JK: 5U (P) or 3U (SP)) are based on manual date evaluations of the 1990ties. A study by order Federal highway Research institutes (BAST) should check the limit values on a clearly broader date basis and if necessary derive recommendations for modifications. The investigation from 2008 confirmed the investigation periods of 1JK and 3JK and suggests only low changes (e.g., 1JK with the criteria: from 5Ug to 7Ug). Clearly the need of separate limit values became for inside and outside urban areas routes as well as highways. In 2010 this scientific knowledge is transferred by a professional committee in application values suited for practise and is considered in the treatment of the leaflet "evaluation by traffic accidents".

To go further more in 2010 UDV will reassess the situation in Germany and the results will show where the process in Germany had to be focused on. It seems that there is still not the acceptance to the qualification process that is been needed. A few states may still thing that a legal note is all they need for an effective Accident Committee work. In conclusion, it may be stated that many steps have still to be taken until in all Federal States as much importance is attached to the work of the Accident Committees as should be.

Besides that monitoring and researching process, the method “Accident investigation with Accident Commission” is a successful story, one that should spread out in other countries too.

In conclusion, it may be stated that many steps have still to be taken until in all Federal States as much importance is attached to the work of the Accident Committees as should be.

REFERENCES


ROAD CRASH AND VICTIM INFORMATION SYSTEM (RCVIS)

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ABSTRACT

Since 1995, three different ministries (Public Work and Transport, Interior, and Health) have been involved in road traffic accident data collection in Cambodia. In 2004, a need for improvement was observed, as the accident databases in those ministries were under reported, limited in their scope, discrepant and were not compatible. For these reasons, Handicap International Belgium (HIB) initiated a project to set up a new Road Crash and Victim Information System (RCVIS) in accordance with the requirements of ASEAN and the United Nations and aligned to the National Road Safety Action Plan of Cambodia, in collaboration with the above-mentioned ministries and WHO to provide government and development stakeholders in Cambodia with accurate, continuous and comprehensive information on road traffic crashes and victims for the purposes of increased understanding of the current road safety situation, planning appropriate responses and evaluating impact of current and future initiatives. The system is based on RCVIS forms, which are filled and sent every month by traffic police and hospital staff from all provinces. The operation cycle of the system consists of data collection, data verification and follows up, data entry and storage, data check and analysis, monthly/annual report production, and report dissemination. The system is implemented via existing networks of the government with limited financial resources, but covering all provinces. It has become a tool to lobby the government for higher commitment on road safety, especially in the approval of the national road traffic law and road safety week. RCVIS is disseminated regularly in soft and hard copy, and through main national media (newspapers, magazines, radio and TVs) every month. To ensure the sustainability of the system, RCVIS is being progressively transferred to the National Road Safety Committee and relevant ministries. Trainings and appropriated staff have been identified in the government to ensure full capacity of managing the data at the end of 2009. In addition, based on this successful experience, RCVIS will be extended into broader injury surveillance system under the ministry of Health next year.
1. INTRODUCTION

Since 1995, road crash data was collected by three different ministries (Public Work and Transport, Interior, and Health). Although the databases developed by these ministries provided relevant indications on the road safety situation of Cambodia, a need for improvement was observed, as the crash databases in those ministries were under reported, limited in their scope, discrepant and were not compatible.

The data collected by the Ministries clearly demonstrated the growing seriousness of road crashes in the country. To fight this problem, the Government of Cambodia, with the support of the Asian Development Bank, adopted a National Road Safety Action Plan 2006-2010 to prevent road crashes and reduce injuries and deaths. The action plan consists of 15 actions, covering all aspects of road safety. Action 2 of this plan highlighted the need to setup a national database on road traffic crashes and casualties.

For these above reasons, in early 2004, Handicap International Belgium (HIB), with support from the French Cooperation, Belgian Cooperation and WHO, proposed to the three ministries above to assist them to develop a new system, based on a standardized and more detailed data collection form.

The new system has been progressively developed since the 1st of March 2004, in accordance with the requirements of ASEAN and the United Nations, and aligned to Action 2 (Road crash Data Systems) of the National Road Safety Action Plan of the Royal Government of Cambodia. The system has been progressively extended to cover for all provinces in Cambodia and equipped with the global positioning system (GPS).

The term: “road crash” means a collision involving at least one vehicle in motion on a public or private road on the Cambodian territory that results in at least one person being injured or killed (WHO 2004).

The objective of the Road Crash and Victim Information System (RCVIS) is to provide government and development stakeholders in Cambodia with accurate, continuous and comprehensive information on road crash and victims for the purposes of increased understanding of the current road safety situation, planning appropriate responses and policy, and evaluating impact of current and future initiatives.

2. SYSTEM STRUCTURE

In 2006, the Cambodian Demographic and Health Survey indeed estimated the number of road traffic casualties at around 122,800. We estimate that this figure is more close to the reality, which would make an average daily number of road traffic casualties of 340. Based on traffic police only reports 60% of serious injured, which is underestimate the real number of road crash casualties. To avoid this underreporting, the Road Crash and Victim Information System (RCVIS) determined that the necessary data sources are based on the existing data sources from both the traffic police and hospitals to become a comprehensive and unique system in Cambodia. To ensure high quality data collection, Handicap International Belgium, in collaboration with Ministry of Interior and Ministry of Health, organized trainings on the use of data collection forms to district traffic police, and to health centers and referral hospitals staff in 24 provinces.
The combination of existing data sources is a good strategy to complement the data between both data sources and to access the magnitude of road crash situation. However, duplication of data from the health structures and traffic police is a serious challenge for the RCVIS system, and the data team does not yet possess matching software to overcome the problem. It requires the team to crossed-check the data manually every month.

2.1 System coverage

By the end of 2006, RCVIS covered 24 Cambodian provinces with traffic police and health facilities data.

![RCVIS geographical coverage by December 2006](Image)

2.2 Current organization

The following figure shows the data transferring from district level to the ministry level. Both ministries are responsible to collect data from their provincial officers, while HIB is responsible to centralize the data from both ministries and private clinics and publish the reports.
The Ministry of Health is in charge of the data collection within hospitals. It provides trainings to hospital staffs, in collaboration with Handicap International Belgium, collects the data at provincial levels and centralizes them in Phnom Penh. The hospital forms have been filled by around 800 staffs in hospitals and health centers.

The Ministry of Interior is the main actor in charge of the data collection by traffic police officers. Their Order Department takes ownership of the system and provides trainings to traffic police officers, in collaboration with HIB, to ensure the completion of the crash data collection form. They also use Global Position System to identify crash locations and black spot. The department then collects data from provincial traffic police offices and centralizes
them in Phnom Penh. There are around 500 traffic police officers regularly filling the form throughout the country.

**Figure 4: RCVIS organization chart under the Ministry of Interior**

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At the national level Handicap International Belgium staff currently collects the RCVIS forms from the MoI for traffic police data and from the MoH for hospital data. HIB also collects forms directly from private clinics. HIB manages the RCVIS database to ensure data entry, data analysis and dissemination of reports. The RCVIS project manager is responsible for the whole process of the system, under the direct supervision of the Road Safety program manager. The project also gets the support and advice from the coordinator of operations and the country director.

**Figure 5: RCVIS organization chart under Handicap International Belgium**
3. SYSTEM OPERATION

The operation cycle of the system consists of data collection, data verification and follow up, data entry and storage, data check and analysis, monthly/annual report production, and report dissemination.

Figure 6: RCVIS system operation

3.1 Data collection

There are two different RCVIS forms. The first is used by traffic police and it concentrates on the type and causes of accidents, while the second one is filled by hospital and health center staff and focuses on the type and severity of injury. In general, traffic police officers are not presents at all crash scenes and do not report all crashes they witness. Hospital data is therefore needed to complement traffic police data. Then, the forms are sent to the relevant national levels (ministry offices) at the end of each month.

3.2 Data verification and follow up

The overall purpose of data verification and follow up is to obtain feedback about the data collection and the quality of the form to increase the effectiveness of data collection from provinces as well as the qualities of data collection form filling to meet the objective of the system. To increase the effectiveness, related ministries and HIB has assigned a staff in their institute to follow up the data collection form from provinces and provide feedback the completeness and validity of the data recorded by traffic police and health facilities. Examining the percentage of “unknown” or “blank” responses to items is an easy measure of data quality. By the end of each month, if ministries do not received from any provinces on time, the ministries will contact to those province to resend the form to ministries. Focal points will justify the report produced by HIB and Ministries to make sure that all cases are reported properly and take measure to solve the entire problem.
3.3 Data entry and storage

After the verification, the forms are entered into the database by using the system which is containing the friendly user interface for traffic police and hospital form. To enter the data into database the data encoder have to understand the technical word in the form to avoid entering incorrectly but anyway, during data entering, the applications are designed to prevent confusion/mistake by the database encoder. For example, victim is a motorbike rider, so seatbelt is not applicable. After completing the entry, the data will be stored in the database management system.

3.4 Data check and analysis

Data check is made to find out duplicated data entry between information from traffic police and hospital staffs to avoid double entries between health facilities and traffic police data. If a casualty is reported by a health facility as well as by the traffic police, it will be taken into account only once as hospital data. To check double entries, the common core variables such as name of victims, accident date, time, type of road user, type of transport, location of crash, severity of injury, hospital discharge are used to determine duplicated data entry. The checking process is complicated and is therefore required to be conducted manually. Further data analysis is also generated through SPSS and MS Excel. The important of the results of the analysis of crashes and injuries are given the recommendation which is the implication of this analysis for policy change and the identification of countermeasures for specific action. In addition the data is analysis to evaluate the trend of fatality rate, helmet rate, head injury, blackspot treatment...etc. the evaluation of the data is to determine any improvements that could be made in future phases and the effectiveness of each countermeasure in terms of the reduction of the number and severity of crashes, and injuries.

3.5 Monthly/annual report production

The report is produced both in Khmer and English version and the content of the report depicts the comparison of evolution or trend from month to month, or year to year. Unusual changes/number can be noticed, and reviewed again in the database. It also provides the recommendation following the safe systems approach promoted by the World Health Organization as the most comprehensive way to deal with road safety and it is based on the understanding that the human body is vulnerable and that the risk of serious injury increases the greater the impact of the crash. Therefore, it involves identifying the potential areas of intervention based on the interactions between the road user, the vehicle and the road environment to reduce crashes, and the severity of injuries. It also provide critical issues related to the current situation of the country, for example the report highlights the drink driving during the Khmer New Year, or number of victims wearing a helmet after a period of the helmet enforcement. If a cause of the change and recommendation are found out, it will be also included in the report.

3.6 Monthly/annual report dissemination

In order to create a widespread awareness of road crash information, it is important to publish monthly and annual reports showing clearly the magnitude and nature of road crash issue. Road crash is a problem that requires activity in many different sectors for improvements to be achieved. The RCVIS monthly and annual reports need to be distributed widely to all
agencies with responsibilities in road safety and with the ability to influence road safety. The RCVIS report has been send to the all agencies regularly through in soft and hardcopy to a total of more than 400 end users, including the National Road Safety Committee (NRSC), Ministry of Interior, Ministry of Health, Ministry of Public Work and Transport, Ministry of Information, National Assembly, media (TV, newspaper, radio), and local and international non-governmental organizations. To increase effective way of disseminate the report to all people around the world to learn more on road safety situation in Cambodia, the RCVIS report has been uploaded into the road safety website of Cambodia (www.roadsafetycambodia.info), which was initiated by Handicap International Belgium and is one of the important tools to disseminate the RCVIS reports and other road safety related information, was developed in collaboration with National Road Safety Committee. The website is based on the 15 action plans of National Road Safety Committee.

3.7 End-user and feedback

At the end of the annual reports, a feedback form is attached to receive comments or feedback from end users. Readers can fill in the form and send to Handicap International Belgium via e-mail or hard copy. All comments are welcome and will be add in to the report. Anyway, if the end user needs more information according to their need, they can send email to the person responsible for RCVIS to produce the customized report for them.

4. GLOBAL POSITIONING SYSTEM (GPS)

The traffic police and health reports are covering just a limited part of the reported crash and casualties, the contents of the report is insufficient to be used in studying the factors affecting the number of the accidents, and if available there is no specific locations are given which might help in the application of the GIS (Geographic Information Systems) technology in identification of these black spots. Road safety can only be improved when we understand the causes and consequences of road accidents/collisions. Analyzing the causes and consequences of crashes are important to work out remedial measures. Therefore, there is a real need to keep a database that should be planned, designed and implemented according to new standards and tools that include GPS and GIS.

From July 2006, Handicap International Belgium and National Road Safety Committee decided to introduce Global Position System (GPS) devices to the traffic police in Phnom Penh and in provinces in the following year. The benefit of using GPS device allowing us now to exactly locate crashes, using GIS data. On the medium term, this will enable RCVIS to identify on the Cambodian Road Network, the locations of crashes easily, quickly and accurately. The data has been used to identify the blackspot of crashes and understand the nature of crash as well as priority actions to improve the physical condition or management of hazardous locations with a history of crashes involving death or serious injury, by implementing appropriate treatments at these locations. The following example picture shows the fatalities road crash on Cambodian Road Network:
In Cambodia, there is no accepted definition of a ‘blackspot’ yet. To be classified as blackspots, sites are generally assessed in terms of their degree and number of crashes. The risk of a crash is not uniform throughout the road network. At certain locations the level of risk will be higher than the general level of risk in surrounding areas. Crashes will tend to be concentrated at these relatively high-risk locations. Locations which have an abnormally high number of crashes are described by the term ‘black spot’ locations. In this report, the term is used, to refer to sections of roads, not on a precise location such as a busy intersection.

5. USEFULNESS OF THE SYSTEM

5.1 Increase of political will

Through the RCVIS report, media play an important role in distributing the information related to the road safety to the public and to increase the political commitment of the Cambodian government. Due to the RCVIS data, the government took action to enforce the traffic law, to develop the helmet action plan and road policing strategy enforcement 2008-2013, national road safety policy, as well as develop a blackspot improvement programme.

5.2 Improvement of blackspots

The use of Global Positioning System by traffic police provides more information related to road crashes and can identify black spots along the national road network. The Ministry of Public Work and Transport, in collaboration with JICA, are now using the blackspot data to plan appropriate remedial actions at these dangerous locations along the national road network. TICO, an emergency response organization, uses the data to locate their ambulances close to spots with frequent crashes.
5.3 Reference to develop plans and proposals

Data is the reference for all road safety stakeholders (NRSC, MOH, WHO, GRSP) to develop strategies, proposals, documents in the Cambodian road safety sector. Especially it is used by National Institute of Statistics, Ministry of Planning.

5.4 Evaluation tools for RS action

RCVIS data has been used as an evaluation tool to measure the effectiveness and impact of project implementation, such as helmet promotion and community-based education projects. Local and international organization, UN agency, and private company have contributed to promote road safety through activities awareness in their organizations and communities. To gain the effectiveness in the reduction of road crashes and injuries, they usually have coordination meetings to update road safety activities, identify overlap in activities, and share information.

5.5 Extension to another system

Based on the experiences in RCVIS, the Ministry of Health has decided to extend the system into a broader Injury Surveillance System (ISS), which will include data on injuries due to road traffic, but also to various other causes, such as falls, domestic violence, and drowning.

6. CHALLENGES

- **Further data analysis**: as data has been collected since 2004 and it has covered broad information from hospital and traffic police sources, further analysis is needed to maximize the utility of the available data. This requires RCVIS team to increase this knowledge in accordance to the local situation and the comparison with international experiences.

- **Increased under-reporting**: though the data collection forms have been collected punctually since 2004, the number of crashes is still under reported and it is increasing from year to year. This is largely due to the fact that the health structures are not filling in the data forms regularly as compared to previous years.

- **Capacity of government staff in province**: the government staffs at provincial level need more support due to the capacity of human resource is limited as well as lack of material so we need more time to provide them the technical related to the system.

- **Upgrading the data system**: is one of our challenges because the RCVIS database system will be transferred to related ministries by the beginning of 2010. Therefore, we have to develop the database system for Ministry of Interior and Injury Surveillance database system for Ministry of Health, as well as the RCVIS database system for National Road Safety Committee. It means that RCIVS database system based in National Road Safety Committee will integrate raw crash data from Ministries of Interior and Health.
- **Create RCVIS working group and hand over the RCVIS:** this issue is very important related to the sustainability of the system after transferring to the ministries in the beginning of 2010. Creating RCVIS working group which combine the staff from related ministries to take responsibility of the system is a complicated task. The other issues the challenge of handing over of the database system management to those ministries due to the lack of capacity of the ministries staff.

- **Integrating RCVIS into E-government system:** in 2010, we plan to integrate the RCVIS into E-government system which is a system supported by the government of South Korea for Cambodian government in the management of information from other provinces to the central ministries in Phnom Penh. The objective of such integration is that we would like to extend the use of RCVIS database system in provincial level without sending the data collection form to the ministries level. The integration is still facing some obstacle due to the system is not running well yet and need to lobby the council ministry to accept the system.

7. **LESSONS LEARNT**

- Collect the data from both sources and integrate to be a unique system which shows the situation of injuries in Cambodia as role model in the developing countries.

- Collaboration between 3 ministries is vital to the successful functioning of the system because those ministries play an important role in data collection in the country.

- Integrating RCVIS into the existing government structure is best for sustainability of the system because RCVIS is an action plan among 15 national road safety action plans of the royal government of Cambodia.

- Accurate and timely data is critical for raising awareness of the road crash issue, and for advocating for greater commitment from government authorities for road safety.

8. **FUTURE STRUCTURE**

HIB will continue supporting the implementation of the RCVIS in 2009 while ensuring a transfer of the system management to the MoI, MoH and General Secretariat of the National Road Safety Committee (GSNRSC). In 2010, HIB expects that the MoI will fully manage the collection and processing of data from traffic police, while NRSC will manage the RCVIS (with the technical support of HIB expected for two additional years). The MoH will also fully manage a new injury surveillance system (ISS), which will collect data not only on road traffic injuries but also on other kinds of injuries such as falls, domestic accidents, violence and drowning. Appropriate trainings will be conducted to appointed staff in those three organizations throughout the coming year. In a long term view, the injury surveillance database system will be decentralized to the local levels. It will be installed in qualified hospitals/health centers, which can ensure more sustainability of the system. The injury forms will be filled by staffs and entered directly into the system at the local levels. Then, only softcopies will be sent to the national level to integrate along with other provincial data into the national reports. To effectively manage this process, strong commitment and qualification of the hospitals/health centers will be required.
Extensive trainings for MoH staff will be organized by HIB on the database management (data entry and verification, form filing system, quality control and assurance, system maintenance and back-up, and analyzing) as well as production and dissemination of monthly and annual reports. As a next step, those staff in MoH will transfer those skills to staffs in selected provinces as part of the decentralization of the system. The following figure shows the future structure of RCVIS:

![Figure 7: Future structure of the systems]

9. CONCLUSION

Road crash and victim information system (RCVIS) has combined two data sources from traffic police and health data to be a unique system in Cambodia as model in developing countries. It provides the accurate, continuo and comprehensive information which can access the magnitude of the road crash situation for reference to develop action plan, proposal, and strategy. It also has been adopted as a broader Injury Surveillance System (ISS). In addition, Global Positioning System (GPS) is integrated into this system. This data is useful to identify crash locations, black spots and provides a deeper analysis on crashes. This information is being used by authorities and agencies active in the road safety sector, especially the Ministry of Public Work and Transport for interventions to reduce crashes and casualties on the road of Cambodia. Since 2009, the RCVIS is in the progress of handover to General Secretariat of the National Road Safety Committee (GSRSC), Ministry of Interior and Ministry of Health. Training have been providing to government staff to ensure full capacity of managing the data.

Through its latest annual report, RCVIS has clearly highlighted road crashes are a major cause of death, injury and disability, especially among younger age groups. They negatively impact on individuals, families and communities, as well as the Royal Government of Cambodia. The RCVIS Annual Report 2008 reviews the main road crash trends in Cambodia compared to previous years. The report shows that over the last 5 years, the number of crashes increased by 150% and the number of fatalities has almost doubled. At the same time, the population has increased by 6% and the number of registered motorized vehicles has increased by 132%. The
fatality rate per 10,000 registered vehicles has decreased from 17.8 in 2007 to 15.1 in 2008 although this number is still more than double the national target, which is set in the National Road Safety Action Plan. Human error by road users is the leading cause of crashes and casualties on the roads of Cambodia, specifically dangerous behaviors such as excessive and inappropriate speed, drink-driving, dangerous overtaking and low helmet wearing rates.

In addition to those quantitative statistics, RCVIS also has played an important role to provide priority recommendations for the Cambodian road safety sector, based on safe system approaches:

**Safer Road Users**
1) Enforce speeding, drink-driving and helmet laws
2) Targeted Awareness Campaigns and Education
3) Improve Driver Training Schools

**Safer Road Environments**
4) Black spot treatment in Phnom Penh and along National Roads
5) Creating safer environments along roads for children and pedestrians

**Safer Vehicles**
6) Phase-out of right-hand drive vehicles
7) Include a seatbelt check requirement in the vehicle inspection process
8) Develop a motorcycle helmet standard

**Safe Systems Management**
9) Management, Coordination and Funding
10) Research
11) Emergency Medical Services

10. REFERENCES

Handicap International Belgium (2005), RCVIS Guideline, Cambodia
Bureau of Transport and Communications Economics, Canberra May 1995, Evaluation of the black spot program,
A DATA QUALITY CASE STUDY FOR TURKISH HIGHWAY ACCIDENT DATA SETS

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ABSTRACT

The highway accident data provides valuable information such as accident black spot locations and their spatio-temporal change to the experts. With the help of this information, experts may take timely precautions in order to prevent the incidents from happening in the future. There is a challenging detail here. Highway accident data is often manually collected. For example, an officer submits the whereabouts of accidents in terms of latitude and longitude on a form or on a map to the system. Although many systems are designed to verify the legitimacy of the data to be entered, systems can still be prone to user errors. Users may enter illegitimate values which appear to be valid in the system, i.e. a point that is not on a highway (an outlier) or a point on the highway but not correctly entered (an inlier). These erroneous values are called disguised missing data and yet can arise in many different data sets such as health or survey apart from spatial data sets. However, the way they emerge and the way they appear in spatial data sets such as in the highway accident data sets is different and detection is difficult compared to that of survey and health-related data sets. Consequently, their presence can affect the outcome of data analysis tasks severely which may cause decision makers to make inaccurate decisions. Therefore elimination of these values becomes a necessity prior to the data analysis.

In this paper, we will explain the common disguised missing value problems in Turkish highway accident data sets. Since the hotspot analysis will be run after data quality is guaranteed, we have focused on disguised missing values on coordinate information. We will describe a framework about how to detect such values automatically. We believe that the results of this study will be of benefit to the data analysts who are working with similar data sets.

1 INTRODUCTION

Every day important decisions are made based on the data stored within databases. There is a challenging detail; the decisions that are made are only as good as the data upon which they are based on (Hulse, Khoshgoftaar, & Huang, 2007). Consequently data quality has a severe impact on analysis.

There are many definitions of data quality but the most frequently used one is: A collection of data X is of higher quality than a collection of data Y if X meets customer needs better than Y (Redman, 1997). Most basically it is the fitness of use which implies that data quality is inherently subjective.
Data quality is a multidimensional concept. In data quality assessments each organization must determine which dimensions are important to its operations and precisely define the variables that constitute the dimensions.

The accuracy of data can be affected negatively by disguised missing data which is the main topic of this paper. Some user interface or database designs may lead user to enter spurious values. Databases that are designed so as not to allow any “null” or “unknown” values can be given as an example. In such cases, users may act in two ways: The first one is to choose the first available entry in a select box (if provided). For example attribute birth date is generally wanted to be disclosed and January 1 (the first value in the pop-up lists of month and day, respectively) may be chosen in order to skip the question.

The second one is to enter any legitimate value to indicate “unknown”. For example, consider a system where the user is required to select a certain city as place of birth but only the cities in Turkey can be selected from the list. If the user was born outside Turkey, the user will tend to select the first available entry in the list such as city of “Adana”. On the other hand, there will be people who were actually born in Adana. As a result, the system will comprise both accurate and inaccurate data entries. If a legitimate value is used frequently in lieu of missing values, it is called a disguised missing value.

2 BACKGROUND

While formulating the strategies and safety plans or assessing the effectiveness of road safety programs, the availability of accurate and reliable data is of paramount importance. However, information systems that are designed to collect road safety data may be implemented without taking into account data collection and quality factors. As a consequence, to derive statistics from these databases individually as well as collectively often constitutes a handicap. The reason of poor quality data is that data normally does not originate from systems that were set up with the primary goal of mining this data.

For example, it is difficult to compare the statistics derived from such road accident databases in different countries due to the discrepancies in the data collection policies. The varying definitional issues such as “road safety fatality” in different countries, underreporting problems and inaccurately collected data are the most common data quality problems encountered in road safety databases (Peden & Toroyan, 2005). Although there is an international agreement on the definition of “road safety fatality” as “any person killed immediately or dying within 30 days as a result of an injury accident”, many countries may apply different definitions. Underreporting problems may occur but can be tackled to some degree by utilizing the output of hospital information systems together with the police databases. A lack of professionals trained in road safety means that data such as the number of people seriously injured, crash location, type of road user (pedestrian or not), and fatalities may not be collected correctly thus impairing the quality of data required to evaluate road safety interventions.

Many studies have been conducted to assess the data quality of road safety databases. The three aspects of data quality that are completeness, timeliness and accuracy have been measured in Canada’s National Collision Database (Chouinard & Lecuyer, 2009). They have found that while database completeness differs significantly among the province/territories for fatal and serious injury collisions, there appears to be a tradeoff between the timeliness and completeness of data in many jurisdictions.

The completeness factor has also been measured for road traffic crash data in Ghana (Salifu & Ackaah, 2009). The level of under-reporting has been analyzed by generating relevant alternative data based on surveys conducted at hospitals and among drivers and then matching this data with that of records in police crash data files and official databases. Such a
data linkage methodology is one of the most common approach in which routinely collected police reports of traffic accidents and hospital discharge files are individually matched or "linked" using a computerized procedure. Using additional data resources in order to improve data quality and to obtain more accurate statistics is a widely used technique. For example, a risk index has been developed which is not solely based on collision statistics but also subjective evaluation techniques (Leur & Sayed, 2002).

Advancements in technology such as the use of GPS devices may help to improve the data quality but are not yet alone sufficient. A good data quality policy should also take into consideration the human factors, i.e. competency in accident investigation, attention in reporting, constant user feedback to induce system improvement are just few to name (Transportation Research Board National Research Council, 1991). Standard definitions, implementing quality control systems, simplifying data requirements, and mandatory reporting are also accounted for part of a successful data quality plan (Elsig, 2009).

3 DATABASE CHARACTERISTICS

Road safety accidents are stored in a relational database which is used by all traffic inspectorates in Turkey. When an accident takes place, the local officer should enter the details of the accident, i.e. time and date of the accident, town, city, the road name, road type, accident type, number of dead and wounded people, latitude and longitude of the accident. All of which are mandatory. You can see a subset of accidents recorded in Adana in Table 1.

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<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Day of the Week</th>
<th>Province</th>
<th>Local Officer</th>
<th>Name of the Road</th>
<th># Dead people</th>
<th># Wounded People</th>
<th>X Coordinate</th>
<th>Y Coordinate</th>
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<td>35,3313</td>
<td>37,023</td>
</tr>
<tr>
<td>2006</td>
<td>12</td>
<td>25</td>
<td>Monday</td>
<td>SEYHAN</td>
<td>ADANA-Bölge Trafik Denetli</td>
<td>51-02</td>
<td>0</td>
<td>3</td>
<td>35,2189</td>
<td>37,029</td>
</tr>
<tr>
<td>2006</td>
<td>9</td>
<td>28</td>
<td>Thursday</td>
<td>SEYHAN</td>
<td>ADANA-Bölge Trafik Denetli</td>
<td>51-01</td>
<td>1</td>
<td>18</td>
<td>35,267</td>
<td>37,051</td>
</tr>
</tbody>
</table>

Table 1: Highway Accidents Database show the accidents information for provinces in Adana city

The system implements basic data quality checks. For example, an officer is not allowed to enter a coordinate outside the region of the traffic inspectorate. The system lets officers to put the requested information only in specific formats and range such that users cannot select an invalid date or road name.

4 A DATA QUALITY PROBLEM: DISGUISED MISSING DATA

Although the system does some checks with respect to ensuring data integrity and quality, it still suffers from some problems. The typical problems we have encountered are as follows:

a. GPS devices may malfunction due to a problem in the projection system and consequently inaccurate coordinate information may be obtained.

b. Longitude information may be entered in lieu of latitudes and vice versa. This situation arises when these coordinates are very close in a particular town.

c. Users may enter the coordinate information inaccurately in the database.

d. The coordinate information may be obtained before GPS devices get ready (GPS devices should receive information from at least three satellites for an accurate measure.)
e. The borders of a town or city may be changed or may have been defined incorrectly in the system’s database.

f. Users may enter the same coordinates to the database systematically for any given points. The reasons may be numerous: users may not know the exact location; users may enter the same values to save time and it is easy; users may use dated reports to enter values. Such values are called as disguised missing values.

Disguised missing values are often insidious as they are hard to detect. Manual detection is hard and costly. To detect manually the densities of the hotspots can be identified and then can be analyzed further in detail whether they are legitimate or not. Here it is important to emphasize that disguised missing values are frequently entered values and they tend to be detected as hotspots in the analysis. Also one can look into the inconsistencies in the system. For example, the same coordinate may be entered so as to correspond to different towns or road names. Disguised missing data can appear in two different ways:

a. The coordinates may not be on the road and are too far away from the valid range (outliers).

b. Coordinates may appear as valid values i.e. on the road and within the valid range (town boundaries). This type of data is called as inliers.

We noticed that disguised missing values are entered in two different ways in the database:

a. In the first case, the same coordinates are entered systematically to the system. For example, latitude 36 and longitude 37 are always entered instead of indicating the data entry as missing or unknown in city of Osmaniye in Turkey in year 2006 and 2007. Probably the users provided this well-known historical data in the cases where they cannot obtain the exact coordinates or they do not want to spend time to obtain them. You can see some part of the dataset in Table 2.

b. Later case occurs due to GPS, manual entry or system problems. Users may enter spurious coordinate values with minor changes in the decimals. For example, in our accident data set, the points where Y coordinates vary between 41.050 and 41.102 and X coordinates vary between 29.000 and 29.005 are detected as disguised missing values. Even if it is not a particular point, these points which fall into a small area are still called disguised missing values. You can see the example in Figure 3.

---

### Table 2: Highway Accidents Database show the accidents information for provinces in city of Osmaniye

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Day of the Week</th>
<th>Province</th>
<th>Local Officer</th>
<th>Name of the Road</th>
<th># Dead People</th>
<th># Wounded People</th>
<th>X Coordinate</th>
<th>Y Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>5</td>
<td>8</td>
<td>Monday</td>
<td>OSMANİYE-MERKEZ</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-07</td>
<td>0</td>
<td>0</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>10</td>
<td>10</td>
<td>Tuesday</td>
<td>OSMANİYE-MERKEZ</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-07</td>
<td>0</td>
<td>2</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>5</td>
<td>3</td>
<td>Wednesday</td>
<td>DUŞÇI</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-08</td>
<td>0</td>
<td>1</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>3</td>
<td>Saturday</td>
<td>BAHÇE</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-10</td>
<td>0</td>
<td>0</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>27</td>
<td>10</td>
<td>Monday</td>
<td>BAHÇE</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-10</td>
<td>0</td>
<td>0</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>6</td>
<td>3</td>
<td>Saturday</td>
<td>TOPRAKKALE</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-06</td>
<td>0</td>
<td>0</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>27</td>
<td>17</td>
<td>Friday</td>
<td>TOPRAKKALE</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-06</td>
<td>0</td>
<td>0</td>
<td>36,000</td>
<td>37,000</td>
</tr>
<tr>
<td>2006</td>
<td>7</td>
<td>28</td>
<td>Friday</td>
<td>TOPRAKKALE</td>
<td>OSMANİYE-OSMANİYE</td>
<td>32-06</td>
<td>0</td>
<td>1</td>
<td>36,000</td>
<td>37,000</td>
</tr>
</tbody>
</table>

---

### Table 3: Highway Accidents Database show the accidents information for provinces in city of Istanbul

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Day of the Week</th>
<th>Province</th>
<th>Local Officer</th>
<th>Name of the Road</th>
<th># Dead People</th>
<th># Wounded People</th>
<th>X Coordinate</th>
<th>Y Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1</td>
<td>7</td>
<td>Wednesday</td>
<td>KAĞİTHANE</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,000</td>
<td>41,0607</td>
</tr>
<tr>
<td>2008</td>
<td>4</td>
<td>27</td>
<td>Saturday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,000</td>
<td>41,0638</td>
</tr>
<tr>
<td>2008</td>
<td>12</td>
<td>10</td>
<td>Saturday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>7</td>
<td>29,004</td>
<td>41,0669</td>
</tr>
<tr>
<td>2008</td>
<td>6</td>
<td>14</td>
<td>Tuesday</td>
<td>KAĞİTHANE</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,004</td>
<td>41,1006</td>
</tr>
<tr>
<td>2008</td>
<td>3</td>
<td>5</td>
<td>Friday</td>
<td>BEŞİKTAS</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,000</td>
<td>41,1015</td>
</tr>
<tr>
<td>2008</td>
<td>10</td>
<td>10</td>
<td>Friday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,000</td>
<td>41,1102</td>
</tr>
<tr>
<td>2008</td>
<td>5</td>
<td>1</td>
<td>Thursday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Trafik De</td>
<td>01-01</td>
<td>0</td>
<td>0</td>
<td>29,003</td>
<td>41,1394</td>
</tr>
<tr>
<td>2008</td>
<td>3</td>
<td>29</td>
<td>Tuesday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Bölge Tra</td>
<td>02-02</td>
<td>0</td>
<td>0</td>
<td>29,003</td>
<td>41,1013</td>
</tr>
<tr>
<td>2008</td>
<td>2</td>
<td>5</td>
<td>Friday</td>
<td>ŞİŞLİ</td>
<td>ISTANBUL-Bölge Tra</td>
<td>02-05</td>
<td>0</td>
<td>0</td>
<td>29,005</td>
<td>41,1001</td>
</tr>
</tbody>
</table>
Here, it is important to note that disguise values do not have to appear as unique values (as can be seen in Table 3) in spatial domain as they do in survey datasets. In survey datasets, values of an attribute can take a small number of values and one or two values are used as disguised missing values. However in spatial datasets, values of coordinates have much larger domain ranges and it is not plausible to work on only exact points as done in the first case.

Such values particularly when they are in large quantities may affect the outcome of the black spot analyses severely. A point in the area may be marked as black spot although it is not true.

The major inconsistencies regarding the coordinates that have been encountered in the dataset are as follows:

1. The coordinates are not on the road.
2. They may be entered as they belong to different towns in the same city.
3. They may be specified on different roads. For example, the coordinates shown in both Table 2 and Table 3 are entered as they belong to different roads, which is not possible.

Manual checking of all these inconsistencies require significant effort as each tuple in the database should be checked against any inconsistencies as well as on the map whether it is on the road or not.

4.1 Method

We have utilized the method proposed by Hua Ming et.al. (2007). However, we have made some adjustments on the method to improve the results and increase the performance. In the first section, the method will be explained and in the second section, we will describe the improvements we have made:

4.1.1. The Embedded Unbiased Sample (EUS) Heuristic

This approach is based on the heuristic that only a small number of values are frequently used as disguised missing values (one or two in an attribute) in real world data and these values are randomly distributed in the database.

If the GPS data is provided accurately to the system, we expect to see strong correlations between the coordinates and the town, coordinates and the name of the traffic inspectorate, coordinates and the road names, coordinates and the city. If a point is used as a disguise value such as [29;41.05] in city of İstanbul, then it will appear with different attributes values in the database i.e. the same coordinates with different towns, cities, and road names (see Table 3).

The tuples with the coordinates [29;41.05] will have both correctly and incorrectly recorded data.

$$T_{coordinates} = [29.000-29.005;41.050-41.102] = R_{coordinates} + S_{coordinates} = [29.000-29.005;41.050-41.102]$$

$T$ is the recorded table, $S$ is the table including disguised missing values and $R$ is the table with the true values.

EUS was defined as follows (Hua & Pei, 2007):
If \( v \) is a frequently used disguise value on attribute \( A \), then \( T_{A=v} \) contains a large subset \( S_v \subseteq \tilde{T}_{A=v} \) such that \( S_v \) is an **unbiased sample** of \( \tilde{T} \) except for attribute \( A \) where \( \tilde{T}_{A=v} = \{ \tilde{t} \in \tilde{T} \mid \tilde{t}.A = v \} \).

In order to clarify the example, let’s assume that we select tuples having towns as “Sarıyer” in city of Istanbul, then our subset will contain tuples associated with this specific region. We will observe correlation among some of the attributes i.e. only specific road names, name of the traffic inspectorate that records these values in the system will appear with “Sarıyer” in the database. Hence, this chosen subset will be a biased sample of the whole set. On the other hand, the subset including the coordinates [29.41.05] will be an unbiased sample if they appear randomly with other attribute values in the database. If they are in sufficient amount, they will be seen with every value of each attribute in the dataset.

If we select the tuples comprising \( v \) for the attribute \( A \), it will contain both accurate tuples \( \tilde{\tilde{R}} \) and contaminated tuples \( S_v \). As a result, we aim to find the subset \( S_v \) from \( \tilde{T} \) which is unbiased sample of the whole set. In other words, \( S_v \) will be the unbiased sample of \( \tilde{T} \) except for the attribute \( A \).

In order to find disguise values on an attribute \( A \), it is required to find small number of attribute values whose projected databases contain a large subset as an unbiased sample of the whole table. Such attribute values are suspects of frequently used disguise values. The approach is straight forward; the larger the \( S_v \) the more suspicious for being a disguise value the \( v \) is. So we need to find maximal unbiased subset \( M_v \), maximal embedded unbiased ample, or MEUS for short.

While analyzing the subsets, two measures of \( M_v \) must be considered; size and quality. Quality can be defined as how well the subset resembles the distribution of the whole dataset. The values with large MEUS should be reported as the suspicious frequent disguise values. For the attributes that we suspect in the database, \( M_v \) will be calculated and the one with the largest value will be reported as disguised missing value.

The framework and details of the EUS heuristics can be found in (Hua & Pei, 2007)

**4.1.2. Finding Disguised Missing Values in Spatial Datasets**

EUS Heuristics have been successfully attempted on the health data sets. However, the method itself is not very appropriate for spatial datasets for the following reasons: Spatial datasets often include several different coordinate information. It is often costly to calculate the correlation between each attribute values. To gain from performance, we proposed to use “Chi Square Two Sample Test” instead of using correlation based scores.

**Chi Square Two Sample Test** checks whether two data samples come from the same distribution without specifying what that common distribution is. The chi-square two sample test is based on binned data. Binning for both data sets should be the same. The basic idea behind the chi-square two sample test is that the observed number of points in each bin (this is scaled for unequal sample sized) should be similar if the two data samples come from common distributions.

More formally, the chi-square two sample test statistic can be defined as follows. **\( H_0 \): The two samples come from a common distribution.**
**Hₐ:** The two samples do not come from a common distribution.

**Test Statistic:** For the chi-square two sample tests, the data is divided into \( k \) bins and the test statistic is defined as:

\[
x^2 = \sum_{i=1}^{k} \left( \frac{(K_1 R_i - K_2 S_i)^2}{R_i + S_i} \right)
\]

where \( k \) is the number of categories (or bins), \( R_i \) is the observed frequency of bin \( i \) for the first sample, and \( S_i \) is the observed frequency of bin \( i \) for the second. \( K_1 \) and \( K_2 \) are scaling constants that are used to adjust for unequal sample sizes. Specifically,

\[
K_1 = \sqrt{\frac{\sum_{i=1}^{k} S_i}{\sum_{i=1}^{k} R_i}}
\]

\[
K_2 = \sqrt{\frac{\sum_{i=1}^{k} R_i}{\sum_{i=1}^{k} S_i}}
\]

Our aim is to measure the distribution similarity between attribute couples of the dataset and the projected subset. In order to achieve this, we decided to represent the dataset as a means of *value couples* they include. For example we have generated new class labels for all the *value pairs* in attributes \( A_1 \) and \( A_2 \) that appear together. If \( A_1 \) and \( A_2 \) have \( p \) and \( k \) number of categories respectively, we have generated \( pxk \) new class labels, then created a new attribute column and finally put the new class labels that the value couples belong to. We repeated this data transformation for every attribute couple and for a dataset of \( n \) number of attributes we generated a new dataset \( D \) containing \( n^2 \) attributes. As we have generated the dataset which is appropriate for Chi Square Two Sample Test, we have measured the distribution similarity between class labels of the modified dataset and its projected subsets. The value which has the largest projected subset that has a similar distribution with the dataset (Maximal Embedded Unbiased Sample, MEUS) is assigned as the most suspicious disguised missing value.

We have also taken into account the following constraints:

a. The uncorrelated or random attribute dimensions may affect the quality of the EUS heuristics based results negatively (Belen, 2009). One should select the related attributes with the help of an expert or using attribute selection algorithms. This also affects the performance of the method.

b. Binning coordinates is also important. It is necessary for Chi-Square Two Sample Test. We have also noticed that due to system, manual entry or GPS device problems, there are coordinates that are very close to each other but are disguised missing values. This is contrary to the belief that disguised missing value can often be a single value frequently found in a data set (Pearson, 2006).

Due to space limitation, we will not go into the details of these methods in this paper.

4.2 Experiment

4.2.1. Experiment Details and Data Set
Our data set comprises 22 attributes. Date’, ‘Time’, ‘State’, ‘Town’, ‘Number of people died’, ‘Number of people injured’, ‘X coordinate’ and ‘Y coordinate’ are some of these attributes. Since the values of the coordinates were reported as unreliable by the experts, the disguised values were investigated on ‘X coordinate’ and ‘Y coordinate’ which correspond to the latitude and longitude coordinates respectively of the point on the highway where the accident happened.

There are 2 main problems: recorded coordinates are not on a highway and there are inconsistencies between the attribute values. In the former case, recorded coordinates fall into terrain or city centers rather than highways. In the latter case, coordinates are specified on the highways but there are inconsistencies with other attribute fields.

As a point is represented by two coordinates, we should take into consideration both values together instead of analyzing individual attributes while detecting disguised missing values. So we generated new point labels for each $x$ and $y$ couples.

For a dataset with $n$ number of values for $x$ coordinate and $m$ number of values for $y$ coordinate, we obtained $mn$ point labels. Handling hundreds of points is not sensible in spatial data sets. Although many accidents may happen on the same place, coordinates might not be recorded exactly the same but recorded with minor differences. Therefore it is required to work on disguised values of areas not the points. So what we need to know is these areas that are frequently used as disguised values.

We can form regions based on the coordinates. It is better to create these regions with a domain expert if it is possible for more accurate analysis. Here it is important to note that we did not include any domain knowledge like road segments or valid X or Y coordinate ranges that define the boundaries of a city.

As a coordinate has 2 to 4 decimals, we have decided to create regions by using a binning range (e.g. 10, 100). To be on the safe side, we rounded the values by 10, 100, and 1000. We also have run the algorithm without rounding the values as well.

Depending on the characteristics of the dataset, different binning ratios may lead to more appropriate results. In our case rounding by 100 has worked satisfactorily for each dataset.

Since the approach is based on the correlation between attribute couples, we should attach importance to which attributes to cover. Redundant attributes can be eliminated by using feature selection methods such as minimum-redundancy maximum-relevancy algorithm. The goal of the algorithm is to select a feature subset that best characterizes the statistical property of a target classification variable, subject to the constraint that these features are mutually as dissimilar to each other as possible, but marginally as similar to the classification variable as possible (Peng, Long, & Ding, 2005). If we select the classification variable as $A_v$, the attribute comprising the candidate disguised value, we can find out the attributes that are dissimilar to $A_v$ and remove them from the calculations. As a consequence, we will eradicate independent attributes which cause biased results. The method has returned the following features as related: “Official Report Number”, “Name of the Officer”, “Road ID”, “Town” and “Day of the Week”.

351
Selecting the feature subset also increases the computational efficiency which has a vital effect while working with large datasets. Since we are dealing with value sets of attributes, dimension reduction decreases the time required to run the method exponentially.

In our analysis, we worked on the accidents occurred in the cities of Adana, Gaziantep, Hatay, Mersin and Osmaniye in 2006, 2007 and 2008.

<table>
<thead>
<tr>
<th>Year</th>
<th>Adana</th>
<th>Gaziantep</th>
<th>Hatay</th>
<th>Mersin</th>
<th>Osmaniye</th>
<th>Istanbul</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>141</td>
<td>82</td>
<td>32</td>
<td>152</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>147</td>
<td>119</td>
<td>25</td>
<td>160</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>118</td>
<td>137</td>
<td>38</td>
<td>170</td>
<td>95</td>
<td>1379</td>
</tr>
</tbody>
</table>

Table 4: Accidents occurred between 2006-2008

4.2.2. Results

We have consulted to the domain expert to evaluate the results. Our analysis for accidents occurred in Adana in 2006 and 2007 did not come up with a frequent suspicious disguised missing value. However, we have detected an area as a candidate disguised missing area in 2008. There are 11 accident points recorded within the area where X coordinate ranges between 35.746 to 35.754 and Y coordinate ranges between 36.976 to 36.984 (X coordinate is rounded to 35.75 and Y coordinate is rounded to 36.98). These points are on the highways segments. However they contradict with other attributes. For example, coordinate values have been recorded to fall into 3 different roads. Two of these road segments (road names 52-03 and 52-04) are successive but one of them (21-05) is totally irrelevant (see Figure 1). We have discussed our findings with the domain expert and he has confirmed that these values exhibit inconsistencies suggesting that this area should be marked as disguise value.

Figure 1: 11 accident black spots between (35.7507; 36.9881) and (35.7509; 36.9899) were specified on O-21 and O-52 roads in the data set of city of Adana in 2008. The black spots are denoted as a yellow placemark on the map. Due to the resolution, it appears to be one black spot. But there are 11 different points which are very close to each other. Table 2 shows some of these tuples. The area includes disguise values. The problem here lies in the road names. The same black spots are indicated as they belong to different roads that is not possible.

 Courtesy of Google Earth. 
Figure 2: The figure shows a part of the traffic accidents recorded in İstanbul in 2008. A potential disguise value is marked as red cross on the map. This point is entered as it is within the boundaries of Kağthane, Şişli, Beşiktaş and Sarıyer. However, the road name is specified as 01-01 in the database (the first part corresponds to the road number and the second part implies at which kilometer of the road the accident happened such as here the accident happened in the first kilometer of the road 01). The road 01-01 cannot belong to four different towns. Table 3 shows some of these tuples. @Courtesy of Google Earth.

Figure 2 shows the road accidents in İstanbul. We have noticed 27 points were entered in the similar whereabouts i.e. latitude varies between [29-29.005] and longitude varies between [41.05-41.102] in the database. Although these coordinates are only within the boundaries of only one district, four different district names are entered.

Our algorithm returned several areas as the suspicious disguise missing areas for İstanbul. Some of them are not the points on the highways and are consequently approved by the domain expert. We have detected 5 suspicious areas. Three of them (31 tuples in total) are expressed as the areas outside the highways by the domain expert. In two of them, we have observed many inconsistencies. In one of the areas whose X coordinates range between 29 to 29.0046 and Y coordinates range between 41.0597 to 41.1001, 35 accident points are recorded on 2 different highways (01-01 and 02-05) which is impossible (see Figure 2). In addition, the coordinates are specified as belonging to four different districts. Such an abnormality shows that points within that range are not the actual accident points.

Our analysis did not come up with a frequent suspicious disguised missing value for Gaziantep, Mersin and Hatay in any year. When we have consulted to domain expert about this finding, he has confirmed the results and explained that these datasets are reliable.

The most remarkable results are gathered in the state Osmaniye in 2006. In Osmaniye, 66 accidents out of 108 have been recorded to occur at the coordinate (36.00, 37.00) which is apparently suspicious. This value is recorded on 5 different highways and 4 towns. In 2007, the same coordinates are observed in 26 accidents out of 92 accidents.

4.3 Conclusion

Highway accident data sets provide valuable information regarding the detection of the black spots on the road and thus aid officers to take timely precautions to prevent accidents from
happening in the future. However, these results will be trustable if we only have high quality data. In this paper, we have investigated a data quality problem which is the identification of the disguised missing data in the recorded accident data sets of six cities in Turkey. We have found that in the data sets of three cities, there are disguised missing data values. Since we do not follow up any domain constraint, we do not claim that we can find any point which is not on the highway. However, we can handle a more insidious case in which we can find the disguised missing values that can be inlier or outlier.

Here, we want to emphasize that if an area is frequently selected as disguised missing value, it is very likely to be detected as a hotspot. Therefore it is essential to uncover disguised missing values before identifying the hotspots. Otherwise, decisions made based on these counterfeit hotspots will be worthless and pervasive. While detecting disguised missing values, inconsistencies in the tuples are also uncovered which clearly show the problems.

4.4 Discussion and Future Work

While it is impossible to prevent disguised missing values in a dataset, it is possible to prevent users to enter inconsistent values to some extent. Users may tend to enter fake values for various reasons when they are forced to provide a value. Consequently, in particular for such critical and mandatory fields, it may be useful to restrict users to enter a value only within a valid range. For example, when a user enters the town in which the accident occurred, it will be helpful to narrow down the roads to the ones that are in that town and asking user to select one of the given roads. Such guidance will both help the user and motivate him/her to enter actual values. However these approaches do not ensure to prevent all the disguised missing values from happening but they help to eliminate some of them. As we mentioned earlier, we do not include any domain knowledge. For a more accurate result, it may be appropriate to eliminate the points that are not on the highway first and analyzing the disguised missing values later. At that point, algorithm will only return the inliers that are impossible to detect manually.

REFERENCES

ABSTRACT

This paper focuses on the crash database system of the UAE based on a recent study conducted among different professionals and officers from traffic police, health authority, municipality and other agencies. Pros and cons of the existing crash database system have been identified based on the responses of these professionals. Fuzzy and missing areas of the existing crash form, problems faced during the data collection process, scope and skills of the professionals engaged in this field to adopt new technologies, and method of crash data sharing have been analyzed based on the responses of the survey. The analysis indicated the need to revise and improve the existing crash form and database by adding or modifying some data fields like adopting injury severity score (ISS) and using global positioning system (GPS) to identify the exact location of the crash site. The database revisions are mostly needed to increase the usability of the database for purposes such as safety auditing and accounting for pedestrian accidents.

This work presented here provides some recommendations based on the concluding remarks made of the survey data analysis. These recommendations focus on developing a common crash data collection form and corresponding online data entry system, structure of the crash database system, incorporating GIS technology, and modifications of the process of data collection from the crash site.
1 INTRODUCTION

The number of road crashes and the associated severity of injuries in the United Arab Emirates (UAE) are quite alarming. Road crash data of the year 2008 indicates a total of 10,135 injury crashes amongst which are 2071 (20.4%) fatal and serious crashes (UAE MOI, 2008). The rate of fatalities is nearly 25 people per 100,000 residents (UAE MOI, 2008) whereas the fatality rate in the USA in 2008 was 12.5 people per 100,000 residents. (URL: http://www-fars.nhtsa.dot.gov/main/index.aspx). Bener et al (2003) indicates that accident cost more than 2.5% of GNP. Numbers and figures of road crash data indicate that the UAE is witnessing almost a fatality due to road crashes in every eight hours, with 25 injuries every day (UAE Ministry of Interior, 2008). The situation is very alarming and should be thoroughly investigated.

While these alarming figures necessitate immediate remedial actions, these measures cannot be effective without proper diagnosis of the problem. For example, adequate understanding of crash patterns and identification of the exact causes require knowledge of crash location, injury type, road geometry, land-use of road-side, among other factors. It is also necessary to have authentic data and establish a proper and updated database system to collect, store and analyze crash-related information. Cherry et al. (2006) stated that standardizing data-collection methods and accident forms, and incorporating Global Positioning System (GPS) will aid in data accuracy and spatial analysis.

The UAE Government, as part of its strategic vision, aims at undertaking necessary steps to reduce crashes and increase traffic safety. Necessary steps to achieve this aim include the need to design effective databases for information archiving, analysis and dissemination, supported preferably by a Geographical Information System (GIS) for safety auditing purposes and carrying out necessary studies such as hotspots. Traffic safety studies explore the effect of various factors on safety performance, either qualitatively or quantitatively, such as the influence of various geometric features of road design, weather conditions, lighting factor or geographical conditions (Shankar et al., 1995; Khan et al., 2006). Using GIS, the analyst can merge accident and highway data, geo-code the accident data and locations, calculate frequency and rate of accidents, and select a variable for stratification to calculate the mean and standard deviation of accident rates (Liang et al., 2005).

A field-study was designed and carried out by the Roadway, Transportation and Traffic Safety Research Center (RTTSRC) to investigate issues of database needs and concerns. Targeted respondents include traffic police engaged in collecting, storing and managing accident data, and professionals and experts engaged in the same field (from municipalities, transport officials, etc.) or doing research on accidents in the UAE.

One of the objectives of the study was to classify accidents on the basis of their nature, location and locate most accident-prone intersections and links from available data. The second objective was to carry out on a gap analysis by identifying the existing methods of collecting, storing and sharing crash data. Third objective was to investigate the scope of incorporating the GIS technology within the existing crash data collection, storing and sharing system. Fourth objective was to set recommendations based on the survey results obtained from the experts’ opinion.
2 SURVEY METHOD

2.1 Survey Design

Stated preference survey method has been adopted to conduct the survey. People who were surveyed had been placed in a hypothetical situations and asked what they would do if they were faced with this particular choice. Nowadays, the stated preference survey is considered as a proven methodology (Polak et al., 1995).

2.2 Survey Population, Sampling Procedure and Sample Size

Traffic and law enforcement professionals were interviewed from the corresponding police and municipality of each Emirate. Participants’ duties varied but were mostly on the strategic level, such as ensuring interdepartmental and other forms of cooperation, planning long-term goals, suggesting legal amendments and preparing draft legal projects, and being responsible for general public security and traffic, including planning and preparing road traffic safety programs. Participants’ duties were mostly day-to-day and at the operational level, such as deploying the appropriate level of human resources, being responsible for statistics on accidents and enforcement, monitoring and patrolling. Opinions of traffic experts, professors and researchers from other stakeholders were also considered.

In practice, assessment and recommendations of crash database system are commonly done by few experts or consultants using scientific approaches. Therefore, it is not essential to have a minimum number of respondents in case of the survey of traffic law enforcement professionals and experts. Nonetheless, a total of 104 surveys were completed in this study to satisfy the basic statistical minimum requirements of the sample size.

2.3 Data Requirements

The interview was designed to be semi-structured, permitting both quantitative and qualitative comments. Both closed and open questions were used. The interview included the following key areas: national traffic safety policy and strategies, existing crash database structure, crash data collection system, acceptance of new technology and recommendations.

The interview was conducted with two groups of individuals: expert professionals (engaged in the database, geographical information system, road crashes and transportation fields) and crash investigators and data entry personnel.

3 RESULT ANALYSIS

The analysis of the survey results is divided into two parts. The first part focuses mostly on the technical aspects rather than the overall perspective of the database system. It includes the results of the surveys of the crash investigators and data entry personnel. In the second part, the experts’ opinions were analyzed to shed lights on the existing crash data collection form, data quality, data sharing methods among different stakeholders, etc.
3.1 Crash Investigators and Data Entry Personnel

Crash investigators and data entry personnel are engaged directly in collecting crash data from the field and storing these in the database system. The opinions of individuals within this category will probably help in disclosing the problems they face in their daily work and can identify the deficiency elements in the existing crash form and crash database system.

3.1.1 Respondents

The majority of responses were obtained from the city of Al Ain and Abu Dhabi. Most of the respondents are engaged in crash investigation and crash data collection from the field, with an overall experience of about 15 years and an average service duration of 13 years in the current position. Most of the respondents have 5 years or more experience in crash investigation or data entry. About 62% of the respondents are high school certificate holders.

3.1.2 Stakeholders Utilizing Traffic Databases (Violations and Accidents)

Figure 1 illustrates the frequency of using violation and accident databases by the various stakeholders. It can be easily concluded that the traffic police is a dominant user of the traffic databases. Public usage is mostly limited to traffic violation and fines. Universities also use the traffic violation and crash databases for research purposes.

Figure 1: Frequency distribution of stakeholders utilizing traffic databases (violations and accidents) in the UAE.

3.1.3 Type and Method of Data Service Provided

Figures 2A and 2B show the frequency distributions of the responses on the type and methods of provided data service. Providing information to the Government is the main purpose of the data service. The figures indicate that providing database support for the traffic police is one of the major objectives of the data. To provide such services, the respondents mostly use CD and HDD (Figure. B). They also provide data on paper to the user of the database.
Figure 2: Frequency distributions of the responses on (A) type of data service and (B) methods of provided data service

3.1.4 Methods of Data Sharing (Intra- and Inter-Departments)

Figure 3 shows the responses on the methods of data sharing among the various departments and within the same department. Computerized means were identified as the most common methods of data sharing. Hard copies (paper-type) are also quite common. Only 14% of the respondents indicated the use of internet-based services.

Figure 3: Responses on methods of data sharing (intra- and inter-departments)

3.1.5 Methods of Collecting Crash Site Data

The crash data is mainly collected from the site by filling a hard copy of the Crash Form as indicated in Figure 4. Photographs and integrated computer system are occasionally used to capture the crash site information. However, utilization of photographs is not common in all investigated crashes in all emirates. Abu Dhabi and Al Ain police use photographs and some integrated computer systems for field data collection (Table 1).
Figure 4: Responses on the methods of crash site data collection

Table 1: Photographs and Integrated Computer System Use by Traffic Departments

<table>
<thead>
<tr>
<th>Location</th>
<th>Percentage of use of Photographs</th>
<th>Percentage of use of Integrated Computer System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu Dhabi</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>Dubai</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Sharjah</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Ajman</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Ras Al Khaima</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Fujairah</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Al Ain</td>
<td>33</td>
<td>43</td>
</tr>
</tbody>
</table>

3.1.6 Sufficiency of Traffic Crash Report

Figure 5 shows the responses on the sufficiency of TCR to serve the organization’s purposes. The majority of the respondents (46%) indicated that the TCR is sufficient. On the other hand, 31% indicated that the TCR is not entirely sufficient, and 23% clearly indicated deficiencies in the TCR (not fulfilling the organization’s needs).
3.1.7 Difficulties in the Traffic Crash Report

Filling up the “Injury Type” data field is considered the most difficult field to fill in the existing TCR. Respondents also face problems in filling the “Type of Crash” field (Figure 6A). The main reason (respondents identified) is that the crash report does not have figures (illustrations) to understand it clearly (Figure 6B). Besides, they emphasized the lack of training (Figure 6B).

Figure 6: Difficult fields (A) and reasons of difficulties (B) in filling TCR

3.1.8 Sufficiency of Pedestrian Accident Data

Figures 7A and 7B show the responses on the sufficiency of data fields related to pedestrian accidents, and the suggested data fields to rectify the deficiencies. Figure 7A shows that respondents are almost equally divided in their response to the sufficiency of the data fields related to the pedestrian accident in the TCR. Figure 7B shows the responses on the suggested data fields (related to pedestrian crash required) to be added in the existing TCR.
Respondents suggested that more details should be included in the TCR such as the activity of the pedestrian before the hit, the location of the nearby pedestrian crossing, and the type of pedestrian crossing (Figure 7B).

3.2 Analysis of the Experts’ Responses

3.2.1 Respondents

Respondents included various stakeholder categories from health authorities (47%) and Ministry of Interior (police officers) (36%). Other professions such as GIS experts, traffic engineers, civil engineers (from municipalities), and university faculty researchers were also tackled. The respondents work for various governmental and non-governmental organizations in the UAE. Figure 8 shows the percentage of respondents based on their organization.
3.2.2 Difficulties of the Crash Form and Database System

Most of the experts indicated that the current police crash form is brief but without any relevant data for their organization (31%). This was mostly commented by stakeholders’ experts (other than police). A significant portion of the respondents emphasized the inaccuracy and incompleteness of the crash form (Figure 9).

![Figure 9: Expert responses on difficulties in the accident form](image)

Among the respondents concerns is finding the exact crash locations, and the absence of the crash database system.

3.2.3 Usefulness of In-Depth Crash Database for the Organizations

About 97% of the respondents indicated that some in-depth crash database would be quite useful for their organizations. Such in-depth crash database would help in developing and establishing safety policies (51%) and prioritize safety initiatives (40%).

3.2.4 Data Needs

Expert and professional respondents were asked to mention the data fields that would be required for analyzing the accidents (for roadway safety auditing, for medical and Emergency Medical Service (EMS) response assessment, and for vehicle safety performance assessment). Some of the most frequent responses are given in Table 2 for each category.

Table 2: Data Needs (for roadway safety auditing, for medical and EMS response assessment, and for vehicle safety performance assessment)

<table>
<thead>
<tr>
<th>Data Needs for Roadway Safety Auditing</th>
<th>Data Needs for Medical and EMS Assessment</th>
<th>Data Needs for Vehicle Safety Performance Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause of the accident</td>
<td>Nature and type of injury</td>
<td>Age of the vehicle</td>
</tr>
<tr>
<td>Direction of the road</td>
<td>Location of hospital</td>
<td>Safety features of the vehicle</td>
</tr>
<tr>
<td>Location of the accident</td>
<td>Location of accident</td>
<td>Braking condition</td>
</tr>
<tr>
<td>Type of road (lane number and speed)</td>
<td>Injury Severity Score (ISS)</td>
<td>Classification of vehicle</td>
</tr>
<tr>
<td>Number of drivers (cas)</td>
<td>Number of cars involved in one accident</td>
<td>Vehicle damage</td>
</tr>
<tr>
<td>Road planning</td>
<td>EMS response time</td>
<td>Silt belt used</td>
</tr>
<tr>
<td>Data Needs for Roadway Safety Auditing</td>
<td>Data Needs for Medical and EMS Assessment</td>
<td>Data Needs for Vehicle Safety Performance Assessment</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Road features (Curvature, super elevation, etc.)</td>
<td>Time of accident</td>
<td>Location of the accident</td>
</tr>
<tr>
<td>Type of intersection</td>
<td>Response time of EMS</td>
<td>Tire condition</td>
</tr>
<tr>
<td>Database for drivers</td>
<td>EMS facilities</td>
<td>Lighting condition of the vehicle</td>
</tr>
<tr>
<td>Visibility</td>
<td>EMS response time</td>
<td>Vehicle speed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maintenance data of the vehicle</td>
</tr>
</tbody>
</table>

3.2.5 Identification of the Geographical Location of the Crash Site

The provision and identification of crash location is commonly done by phone (people to dispatcher or dispatcher to rescue services). This imposes difficulties and implies delays in the provision of EMS to the crash site. It is quite rare that the GPS readings of the crash location are recorded (although this is an entry of the existing TCR). There are also concerns on the accuracy of such GPS readings (if recorded). 44% of the experts emphasized the need for the exact crash location to be identified via GPS means. Recently, some police departments are taking initiatives to identify a crash phone call through GIS technology. This will help the police and EMS to reach the crash site promptly (URL: [http://gulfnews.com](http://gulfnews.com), 2008). Introducing such GIS technology-based caller identification is recommended for all police departments.

3.2.6 Methods of Data Sharing and Effectiveness of Involving a Third Party

As mentioned earlier, the crash database is critically important for different organizations. There is an urgent need for a secured and efficient method to share the database among the various governmental and research organizations. The expert professionals were asked to mention the most plausible data sharing methods among and within the organizations. 51% of the respondents suggested the internet to be the best medium for data sharing. The latest technologies to share data through internet are powerful, secure and proven to be very efficient and easy media to share data among various stakeholders. On the effectiveness of involving a third party or private sector in the data sharing processes and the potential role, 88% of the respondents indicated that it would be effective to enhance the process by involving a third party. The majority of participants suggested that the involvement should be limited, indicating that the third party involvement should be restricted to gathering data from relevant agencies and maintaining the crash database (Figure 10).
3.2.7 Extension and Methods of Data Sharing Among Various Stakeholders

The experts from different organizations were asked about the extension of the data sharing. Most of them suggested that some limited data access should be given to different organizations based on their needs and requirements (Figure 11A). This would ensure personal data security and confidentiality. Most of the respondents (88%) agreed that the crash data should be available and internet could be a better medium. The partial write access to that database should be limited and done by the authorized organization only. The read access should be available for all. Equal percentage of respondents suggested only one authorized agency with full write access to the database and read access could be made limited or open for all users (Figure 12B). Some concerns were raised on the chance to disclose confidential personal and police information which suggests the need for more studies on this issue before making any final conclusions.

One important finding of this study is that the majority of stakeholders (95% of the respondents) were in favor of sharing the information among other agencies. This may help
the Government and other related agencies to work closely in the future to come up to better road safety policies and enhance the traffic safety measures. Most of the respondents expressed their willingness to participate in developing a nationwide GIS-based crash database, if the Government takes the necessary initiatives. They indicated willingness of allocating resources (personal, monetary and data) to develop such nationwide database GIS system (Figure 12).

Figure 12: Responses on type of resource(s) to be allocated to develop a nationwide internet GIS-based accident database

4 CONCLUSIONS AND RECOMMENDATIONS

From the study, it is clear that in order to achieve the national goals of road safety there is an immediate need to re-examine the data collection methodologies, storage, and maintenance of crash reporting systems of the UAE. Potential improvements were suggested to cover issues of data needs, data sharing, accessibility, involving third parties, etc. The main findings of the study can be summarized as follows:

- Most of the respondents do not maintain a reasonably sound crash database.
- An in-depth crash database will be useful for almost all respondents’ organizations.
- The current database system is quite brief with little relevant data for the respondents’ organizations.
- Injury categorization should be done based on national standards such as ISS.
- Seat belt usage, braking condition, tire condition, pedestrian activity before crash, and location of pedestrian crossing data are required for crash analysis.
- There is an agreement on the need for the exact location of the crash with GPS data.
- Most of the respondents indicated preference of sharing data through internet.
- Involving a third party for gathering data from different agencies and maintaining the database will be helpful.
- Most of the respondents do not have GIS-based crash database system.
- The majority of the professionals indicated that the existing TCR does not fully serve or meet their needs.
- A major portion of the respondents indicated difficulties in filling several data fields such as the “injury type” field.
- A significant portion of the respondents agreed that the pedestrian data in the existing TCR form may not be sufficient.
Some of the recommendations made from the study are as follows:

- Preparation of new TCR Form
- Designing the database using appropriate software
- Preparing a nation-wide GIS based road network map
- Establishing a injury monitoring cell in hospitals
- Installing permanent traffic counters on strategic highways
- Developing on-line web-based GIS database
- Professional training for accident investigators and data entry personnel

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REFERENCE


CHARACTERISTICS OF INJURY CRASHES IN DUBAI, UAE

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ABSTRACT
The global road safety situation is briefly reviewed then focus is brought to the rapidly developing Middle-Eastern country of the United Arab Emirates, and specifically to the emirate and city of Dubai. Road safety is analysed using recent injury crash case files collected from the authorities for the twelve year period (1995-2006).

Some of the key problems found were the high overall severity of crashes and high propensity of pedestrian and single-vehicle crashes. Speeding was found to be the second most common reported cause. Countermeasures were reviewed for effectiveness and selected to match these problem areas. The effectiveness of these countermeasures was used to calculate an estimated reduction in crashes or casualties. Once this improvement in road safety was calculated, an economic calculation of cost savings was possible using UK crash costings in the absence of up-to-date local accident cost estimates. The overall cost savings are found to be significant by any standard, amounting to £350m or AED2.1bn (Dirhams – the local UAE currency). This method can be extended and refined with more detailed crash data. It can also be validated with before/after studies if/when these measures are adopted locally.

1 INTRODUCTION
Road users in the city of Dubai, in the United Arab Emirates, vary by their modes of transport and the way they use these different modes. The era of rail travel dawned in the region in September 2009 with the advent of Dubai Metro while marine transport has been used historically to traverse the Dubai creek. Road transport is the dominant mode of transport, with annual increases in the number of motor vehicles registered (2006: 340,538; 2007: 389,010; 2008: 459,348; Dubai Statistics Centre, 2009b). The city has seen a growth in both resident and active populations over the past few years (Dubai Statistics Centre, 2009a) with a resident population of 1.65m and an active population of 2.45m in 2008. The population only three years before was found in a census to be nearly 1.2m (Ministry of Economy, 2005). With growth in these figures and in so many other dimensions, it follows that traffic will become a concern, both in terms of safety and congestion. The traffic safety dimension has been looked at in neighbouring areas like Abu Dhabi (Almubarak, 1998) with the analysis of crash data from 1989-1990 and for the whole UAE (1990-1992). Specific aspects of road safety have also been investigated by a few workers in the field as shown next in the literature review. However no comprehensive overview of crash data has been recently completed of such a depth as to provide a clear indication of the main areas of concern in road traffic safety, so this study comes at both a timely and critical period in the history of the UAE in general and Dubai in particular.
2 LITERATURE REVIEW

Global estimates of the effect of road crashes on populations vary in their methods and units. Recording or estimating deaths from traffic crashes is one of the earliest methods of counting the effect of adverse road safety, while more recently cost estimates have attempted to calculate this effect in monetary terms.

Recording deaths varies by region and level of development, with the World Health Organisation (WHO) estimating that only 115 countries around the world record this data, with 64 countries only considered to have complete data (Mathers et al, 2005). Estimates of global annual road deaths vary from half a million by TRL (Transport Research Laboratory estimate for 1999) to 1.18m (1998) by WHO (Jacobs et al, 2000). Cost estimates tend to be measured as a percentage of Gross National Product (GNP). This estimate varies according to the level of motorisation (the level of motor vehicle use in a country). TRL estimates that the economic costs of crashes range from 1 to 1.5% for developing countries and those in transition to development, while in highly motorised countries (HMCs) the cost estimate is about 2% of GNP (Jacobs et al, 2000).

Two common measures of comparing road safety between different countries are fatality risk and fatality rate (Jacobs et al, 2000; Kopits & Cropper, 2003). Fatality risk is a measure of the risk to the general population (driving and non-driving) of dying in a road crash, normally measured as the number of fatalities per 100,000 units of population. Fatality rate however is a measure of the number of fatalities per 10,000 motor vehicles. These rates can be used to compare Dubai and the UAE to the best-performing and worst-performing nations in road safety terms in the European Union (EU). Table 1 shows that there is a large difference in fatality measures while motorisation levels do not vary a lot.

Table 1: Comparison of Dubai and the UAE with some Highly Motorised Countries (Aldah, 2009).

<table>
<thead>
<tr>
<th>Country</th>
<th>Motor vehicles per 1,000 population</th>
<th>Fatalities per 100,000 population</th>
<th>Fatalities per 10,000 vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>UAE</td>
<td>217</td>
<td>21.7</td>
<td>10</td>
</tr>
<tr>
<td>UAE (Dubai only, 2005)</td>
<td>525</td>
<td>20.5</td>
<td>3.75</td>
</tr>
<tr>
<td>Greece (2003)</td>
<td>-</td>
<td>14.6</td>
<td>-</td>
</tr>
<tr>
<td>Portugal (2004)</td>
<td>510</td>
<td>12.3</td>
<td>2.4</td>
</tr>
<tr>
<td>United Kingdom (2004)</td>
<td>552</td>
<td>5.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Sweden (2004)</td>
<td>563</td>
<td>5.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Data sources: DfT, 2006; Ashur, 2003; RTA, 2006; Ministry of Economy, 2005.

Unpublished works on road safety in the UAE were found from two sources. Almubarak (1998) used crash data from Abu Dhabi police (1989 – 1990) and the Ministry of Interior (1990 – 1992) to survey road safety at that time, concentrating on the urban area of Abu Dhabi. His findings showed that area to possess an adverse road safety record. Cost estimates were attempted and found that crashes cost approximately 1.5% of GNP (1991 figures). Haj Ahmed (2002) conducted research from the epidemiological perspective on 1995 crashes in the UAE and estimated the total economic costs to be closer to 2-3% of GNP. He also found 18 – 40 year olds the most involved age group in fatal crashes. Most of the data for UAE crashes as described in the previous studies was collected centrally by the Ministry of Interior, which makes it secondary, as opposed to data collected directly from the police as described here, minimising the risk of introducing errors in transmission or transcription.
Published studies on the subject in the UAE were found to be few and far between. A seat belt law introduced in the UAE for front seat occupants of motor vehicles in 1999 was reviewed for its effect on traffic safety (Abdalla, 2005). The findings showed fatalities and serious injuries to have decreased significantly. Another study on seatbelts from hospital admissions in the city of Al-Ain (150km south-east of Dubai) showed that minor injuries increased after introduction of the seat belt law (El-Sadig et al, 2004). Involvement of four-wheel-drive vehicles, pedestrians and young drivers were all highlighted as trends by another hospital-based study in Al-Ain in the year 2000 (Bener et al, 2006) which is indicative of the type of issues facing road safety professionals in the area. Young drivers also featured heavily in a study of crashes in the downtown section of Abu Dhabi city (Ashur et al, 2005).

Drivers were the focus of a couple of other studies based on questionnaires to survey self-reported safety-related behaviour and crash involvement (Al-Madani, 2000; Al-Madani & Al-Janahi, 2002). These studies covered not just the UAE but also the neighbouring countries of Bahrain and Qatar. Drivers with more experience were found to comprehend signs better, though this had little effect on their crash involvement. Drivers with a better understanding of road signs tend to use seat belts more (Al-Madani, 2000). An interesting finding was only 55 – 56% of drivers correctly identified warning and regulatory signs (Al-Madani & Al-Janahi, 2002).

Seat belt use was first legislated in the Australian state of Victoria in 1970 (Wagner, 1997). Over 40 countries had enacted seat belt legislation by 1990 (Evans, 1991) but many countries still have poor seat belt use rates, even with legislation. Seat belt use by traffic casualties admitted to a hospital in the UAE from a recent study in Al-Ain (2003-2004) was found to be very low, with only 29% of drivers and 14% of front-seat passengers using seatbelts, along with 2% of rear-seated adult passengers (Barss et al, 2008). Mandatory seat belt use was estimated to reduce the probability of death for front seat occupants by 40-50% and by 25% for rear seat occupants (Elvik & Vaa, 2004). A meta-analysis of data from numerous studies on the subject showed the average reduction in vehicle occupant injuries to be 12% (ibid.).

Electronic Stability Control (alternately known by many names according to manufacturer/supplier, such as Electronic Stability Program, Dynamic Stability Control, Vehicle Stability Control, etc.) is a relatively recent advancement in active safety. It is designed to sense an impending loss of control (that may preclude a crash) and intervene to regain control, thus decreasing the likelihood of a crash. It was introduced in the late 1990s in passenger cars (Weekes et al, 2009). The effectiveness of this measure has been studied in the USA, Europe and Japan. The results were mostly positive, especially in low-friction situations as found in extreme winter conditions (Aga & Okada, 2003; Farmer, 2004; Kreiss et al, 2005; Lie et al, 2005; Thomas, 2006). An overall effectiveness of 16.7% in reducing most injury crashes was used as estimated by Lie (2005) as that study covered the longest time period (over eight years).

Different styles of pedestrian crossings exist but little difference was found in crash rates (Zaidel & Hocherman, 1987) between the different crossing types. Numerous studies have shown the wide variety of options and safety effects of pedestrian crossings (Corben & Duarte, 2006; Elvik & Vaa, 2004; Reading et al, 1995). The one crossing type singled out in the meta-analysis was signalised pedestrian crossing facilities (upgraded from other crossing types) that have an estimated 30% reduction in injury crashes (Elvik & Vaa, 2004).

Impacts with stationary objects at the road side tend to be severe due to the fixed nature of many roadside objects (trees, utility poles, rocks, etc.). Reviews of roadside crashes and objects (Corben et al, 1997; Elvik & Vaa, 2004; Short & Robertson, 1998) have shown many methods for improving safety at such locations including changes to horizontal road geometry and large-scale shoulder sealing, along with the more traditional guardrails and crash cushions. Crash cushions for impacts at the site of stationary objects on the roadside have an
estimated 69% reduction in injury crashes, from the aggregate meta-analysis on a number of studies (mostly from the USA) by Elvik & Vaa (2004).

Speed limits and driver adherence to these limits have been studied in various locations and conditions. The deviation of drivers from average traffic speeds have been shown to increase their crash rates in a number of studies (Munden, 1967; Aljanahi et al, 1999). Reducing average speeds by 5 kph is claimed to result in a saving of over 11,000 deaths and 180,000 injury crashes annually in the EU (ETSC, 1995). Speed and crash incidence are not always related, as found in a review by Wilmot & Khanal (1999) in the USA, however crash severity was found to be directly linked to speed. Reducing existing speed limits in the higher ranges (from 130 kph down to 120 or 110 kph, and from 120 to 110 kph) was estimated to have an estimated injury crash reduction of 14% (Elvik & Vaa, 2004). The reduction of speeds in the lower speed ranges (70 kph down to 60 and 60 kph down to 50 kph) had a lower estimated effectiveness of 9% in reducing injury crashes, which is still an improvement. Speeds in the lower ranges are particularly relevant to pedestrian traffic safety as impact speeds of above 55 kph used to result in fatalities (Ashton & Mackay, 1979; Ashton, 1982). More recently this fatality threshold might have risen slightly with the improvement in vehicle design (Neal-Sturgess et al, 2002).

The automatic enforcement of speed limits using cameras and radar equipment has seen use in many countries around the world, generally with positive effects (Newstead & Cameron, 2003; Pilkington & Kinra, 2005). The advantage of such devices is the time saving when compared to traditional manned speed cameras (Wilmot & Khanal, 1999) in the man-hours needed for processing. A disadvantage of such a measure is the distance- and time-halo effect which means that traffic might adhere to the limit at the position and time of application only, while continuing to speed outside the area of deployment (Champness et al, 2005; Koushki & Hasan, 2000). The estimated effectiveness of this measure on reducing injury crashes from meta-analysis of a number of studies was 17% (Elvik & Vaa, 2004).

3 METHODOLOGY
Every crash that occurs on the roads of Dubai is required to be reported to the police to get an authorisation of vehicle repair, without which it is difficult to perform any bodywork at a garage or bodyshop. This leads to a fairly comprehensive crash database and little underreporting (Abdalla, 2005; El-Sadig et al, 2002). These crashes are reported to the police and the data are input on a database shared by the police and roads and transport authority (RTA; Aldah, 2009). This database was used to extract all injury cases from 1995-2006 divided into three categories: a vehicle/driver file, a casualty file, and a crash case file. In total 29,856 vehicle/driver files were used with 30,942 casualty files and 18,142 crash files (all linked by the case ID) on a Microsoft Access database. These files contained base-level crash information such as crash date, time and location, with additional fields allocated to the number of parties involved and the reported cause and type of crash, along with local conditions if available. They were imported, sorted and validated using the statistical software known as the Statistical Package for Social Sciences (SPSS Inc, 2006) which was also used for most of the univariate analysis performed.

The results of analysing each variable (in some cases on its own, and in others along with other sub-variables) serve to highlight the most frequently occurring scenarios, such as the most frequent crash types, times, locations, causes and severities. In some cases the results were not significant when compared to different years but when compared to other countries (such as the UK), differences were obvious (such as overall case severities –the percentage of the total injury cases reported to be fatal). After the key problem areas were found, they were matched to safety countermeasures that were found to be effective in previous research studies as reviewed in the literature. Most of these studies on countermeasures also show an
effectiveness level as a percentage reduction in crashes or casualties, which allows the calculation of possible savings if such countermeasures were applied in Dubai.

Such a method was used in many other road safety studies (Corben et al, 1996, 1997; Keall & Newstead, 2007; Mansfield et al, 2008; Welsh & Lenard, 2001) and is common where carrying out individual before/after studies to measure effectiveness locally is not possible due to practical and cost constraints. The calculation of savings in terms of reduced crashes or casualties is straightforward, but calculating financial costs is more complicated due to the different methods available. Where up to date crash costs are not available it is possible to use costings from other countries – in this case the UK was chosen as recent crash costs were available from 2005 (DfT, 2007). Two main cost figures were used from the UK Department for Transport publication: the average cost of a crash where at least one person was injured (£64,440) and the average cost to the economy of treating one casualty from a car crash (£44,920). Most of the countermeasures related to reductions in crashes rather than casualties, so the first figure was most commonly used.

A number of assumptions need to be made as is typical in such work to enable estimated calculations to be made. Some of the key ones were that a similar number of crashes will occur in the next twelve years as has occurred in the past twelve. If more crashes occur, then these calculations might be conservative. The crash costs are not thought to be identical between the UK and UAE however no recent cost estimates were available from the UAE so UK costs were used. Also costs rise with time so again the economic figures might be conservative. The figure arrived at as a summary saving is large and significant by any measure.

Some countermeasures appear to duplicate measures already in existence in the UAE. However these were only suggested where such measures were known to be inactive in the UAE, such as the seatbelt legislation that was effective at the time of enactment but adherence dropped with time to very low levels (Barss et al, 2008). The effectiveness of countermeasures is not always transferable between countries and regions. The extent of transferability is discussed after the results.

4 RESULTS

Some of the key problem areas found from the aggregate data analysis are summarised in Table 2 below. The measure of speeding is subsequently split in to two speed ranges (high and low) in the next two tables as different effectiveness levels apply to these ranges.

Table 2: Key problems that stood out from the crash data analysis for Dubai (1995-2006).

<table>
<thead>
<tr>
<th>No.</th>
<th>Problem found from analysis</th>
<th>Supporting analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High proportion of fatal crashes</td>
<td>13.5% of crashes fatal compared to 1.4% in UK*</td>
</tr>
<tr>
<td>2</td>
<td>Pedestrian crashes are most common type</td>
<td>28.6% of crashes are pedestrian-type, more than any other</td>
</tr>
<tr>
<td>3</td>
<td>High number of single-vehicle crashes</td>
<td>48.7% of cases involve a single vehicle</td>
</tr>
<tr>
<td>4</td>
<td>Urban areas account for many crashes</td>
<td>Most crashes (40.6%) occur on roads with a 60 kph limit, which are in urban areas</td>
</tr>
<tr>
<td>5</td>
<td>Speeding is the 2nd most common crash cause recorded</td>
<td>Accounts for 12.6% of all crashes</td>
</tr>
<tr>
<td>6</td>
<td>Highways account for a lot of crashes</td>
<td>3 of top 6 crash locations are major highways</td>
</tr>
</tbody>
</table>

*Source: DfT, 2006.*
Many of these problems are in common with other areas and findings of previous research as seen in the literature review. Each of these areas was then matched to a countermeasure whose effectiveness is known from previous research (Table 3). This is to enable the calculation of the estimated improvement if that measure was applied universally to this data set (ideally).

Table 3: Problem areas matched to countermeasures (Dubai 1995-2006 injury crashes).

<table>
<thead>
<tr>
<th>No.</th>
<th>Problem area</th>
<th>Countermeasure (and subdivision of problem area to be addressed)</th>
<th>Best estimate of difference in injury occurrence/injury crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>High proportion of fatal crashes</td>
<td>Seat belt use legislation (for vehicle occupants)</td>
<td>-12% (injured vehicle occupants)</td>
</tr>
<tr>
<td>1b</td>
<td>High proportion of fatal crashes</td>
<td>Electronic stability control (to tackle rollovers)</td>
<td>-16.7% (crashes)</td>
</tr>
<tr>
<td>2</td>
<td>Pedestrian crashes are the most common type</td>
<td>Signalised (separate phase) pedestrian crossing facilities (upgrade)</td>
<td>-30% (crashes)</td>
</tr>
<tr>
<td>3</td>
<td>High number of single-vehicle crashes</td>
<td>Crash cushion at site of impact (for stationary object impacts)</td>
<td>-69% (crashes)</td>
</tr>
<tr>
<td>4</td>
<td>Urban areas account for many crashes</td>
<td>Reducing existing speed limits (from 70 → 60 and 60 → 50 kph)</td>
<td>-9% (crashes)</td>
</tr>
<tr>
<td>5</td>
<td>Speeding is the 2nd most common crash cause recorded</td>
<td>Automatic speed enforcement</td>
<td>-17% (crashes)</td>
</tr>
<tr>
<td>6</td>
<td>Highways account for many of crashes</td>
<td>Reducing existing speed limits (to tackle higher speeds on highways) from 130 → 120 or 110, 120 → 110 kph</td>
<td>-14% (crashes)</td>
</tr>
</tbody>
</table>

Source: Lie et al (2005)

The next step is the actual calculation of the estimated savings, either in terms of casualties or injury crashes. The economic cost of every casualty and injury crash is known from a UK Department for Transport publication (DfT, 2007). This allows an overall savings estimate to be made, which is a staggering figure when viewed next to the overall size of the injured population annually (around 300 fatalities and 1500 casualties).
Table 4: Calculation of estimated savings from applying countermeasures to relevant crashes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Countermeasure (and sub-division of problem area to be addressed)</th>
<th>Estimated 12-year crash/casualty reduction (retrospective, rounded to last digit)</th>
<th>Avg. value of est. saving in crash prevention cost (based on UK, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Seat belt use legislation (for vehicle occupants)</td>
<td>12,958 (relevant crashes) × 12% = 1,555 (assuming all non-pedestrians are vehicle occupants)</td>
<td>£44,920 × 1,555 = £69,850,600</td>
</tr>
<tr>
<td>1b</td>
<td>Electronic stability control (to tackle rollovers)</td>
<td>1,970 -16.7% = 329</td>
<td>£64,440 × 329 = £21,200,760</td>
</tr>
<tr>
<td>2</td>
<td>Signalised (separate phase) pedestrian crossing facilities (upgrade)</td>
<td>5,180 -30% = 1,554</td>
<td>£64,440 × 1,554 = £100,139,760</td>
</tr>
<tr>
<td>3</td>
<td>Crash cushion at site of impact (for stationary object impacts)</td>
<td>1,719 -69% = 1,186 (taking all single-vehicle stationary-object injury crashes)</td>
<td>£64,440 × 1,186 = £76,425,840</td>
</tr>
<tr>
<td>4</td>
<td>Reducing existing speed limits (from 70 → 60 and 60 → 50 kph)</td>
<td>7,366 -9% = 663 (on roads with a recorded 60 kph speed limit)</td>
<td>£64,440 × 663 = £42,723,720</td>
</tr>
<tr>
<td>5</td>
<td>Automatic speed enforcement</td>
<td>2,288 -17% = 389 (note: increased use of speed cameras in the final period of study already shifted speeding to 6th leading cause in 2006)</td>
<td>£64,440 × 389 = £25,067,160</td>
</tr>
<tr>
<td>6</td>
<td>Reducing existing speed limits (to tackle higher speeds on highways) from 130 → 120 or 110, 120 → 110 kph</td>
<td>2,150 -14% = 301 (on roads with a recorded 120 kph speed limit)</td>
<td>£64,440 × 301 = £19,396,440</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>4,422 crashes, 1,555 casualties</strong></td>
<td><strong>£354,804,280 ≈ AED2.1bn (UAE Dirham)</strong></td>
</tr>
</tbody>
</table>

Source: DfT (2007)

These were not the sole problem areas and suggested countermeasures identified but they provide a summary of key findings. With more detailed crash information this process can be repeated with better accuracy and confidence of the resulting estimations.

5 DISCUSSION
The results display a range of common road traffic safety ailments along with some traditional and recent countermeasures designed to improve outcomes in a crash, or avoid it altogether. The situation in Dubai is unique in many aspects, and reflects the overall position of the UAE as a growing regional economic powerhouse. With increased development it is not possible to move everything forward and advance at once, but one thing normally leads to another. The interaction with the various stakeholders in collecting this data and conducting the research shows that a lot of attention and investment is directed at the area of roads building, regulating, enforcement and monitoring.
The high proportion of fatal crashes could be tied in with the predominance of 4x4 and large vehicles in the fleet as they appear in a study of Al-Ain city (Bener et al, 2006), which is not far from Dubai and shares a lot of common environmental features. The high-speed highways connecting Dubai with neighbouring cities might also contribute to the high severity of crashes associated with speed. Pedestrians are commonly involved in crashes, which is to be expected in urban areas, but the unusual finding is their involvement in high-speed crashes on highways and areas where pedestrians are not normally expected to be. Contributing to this problem was the lack of pedestrian crossing facilities at such locations even when major developments may lie at opposite sides of a highway. Things are improving now with many airconditioned crossings planned (Al-Theeb, 2007) and completed. A crash between a motor vehicle at highway speeds with a pedestrian is expected to result in a severe injury and possibly death. Pedestrians active in urban city centres are a common safety concern with other countries (Corben & Duarte, 2006) but lower vehicle speeds might make a difference to injury outcomes.

Loss of control crashes involving single vehicles are also likely to happen on highways, especially if the surrounding terrain is monotonous with little visual stimulation, while adverse winter weather conditions are rare in the UAE. The low seatbelt use observed by many studies in the area (Abdalla, 2005; Barrs et al, 2008; El-Sadig et al, 2004) might also contribute to an increased mortality and morbidity from loss-of-control crashes, as unbelted occupants are likely to suffer an increased risk of ejection.

The dynamic and flexible nature of development in Dubai offers a ripe opportunity for trialling any and all of these countermeasures in some way. Then a controlled before-after comparison can be made to see the extent to which effectiveness levels are comparable between Dubai, UAE and different regions.

REFERENCES


Contents session 7  Distraction, fatigue, alcohol and drugs related adverse effects on driving

An Examination of the Effects of Continuous Positive Airway Pressure (CPAP) Treatment on the Driving Performance of Patients Suffering from Sleep Apnoea
Aikaterini Touliou, Centre for Research and Technology Hellas (CERTH)/Hellenic Institute of Transport (HIT), Greece

Drinking and Driving Project in Guangxi
Ann Yuan, GRSP, China

Drug Users Perceptions of Drug Driving Post the Introduction of Random Roadside Drug Testing in Melbourne, Victoria
Laura Ann Wilson, Monash University, Australia

Drinkdriving with Heavy Vehicles in Norway, Prevalence, Accident Risk and Countermeasures
Terje Assum, TØI – Institute of Transport Economics, Norway

Safety Issues of Drowsy/Fatigue Driving and Countermeasure Mitigation
Prof. Azim Eskandarian, Center for Intelligent Systems Research (CISR), The George Washington University, USA
AN EXAMINATION OF THE EFFECTS OF CONTINUOUS POSITIVE AIRWAY PRESSURE (CPAP) TREATMENT ON THE DRIVING PERFORMANCE OF PATIENTS SUFFERING FROM SLEEP APNOEA

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ABSTRACT
Research to-date identifies the obstructive sleep apnoea syndrome (OSAS) as a significant risk factor to motor vehicle accidents (MVAs) and supports that treatment of OSAS using continuous positive air pressure (CPAP) can reduce this risk. As yet, however, there are no generally accepted regulations within the Europe Union concerning driving licensing and OSAS. Thus, it seems pertinent that these regulations are established both for the benefit of the OSAS patients and the safety of all drivers.

In the present study, the main objective was the investigation of the effect of OSAS and alcohol consumption in driving performance, while controlling for limitations of previous research. The performance levels of OSAS patients (N=18) in two conditions, CPAP-treated and untreated, with the performance levels of healthy control participants (N=18) in two conditions, BAC=0% and BAC = 0.5%, has been studied in a series of simulated driving and cognitive functioning tasks.

The results were in agreement with the results of previous research, untreated OSAS patients with an apnoea-hypopnea index >10 showed a worse driving and laboratory test performance than when treated with CPAP. In most of the indicators studied, the deterioration of performance was less severe than the deterioration of performance of healthy control participants in the BAC=0.5% condition. However, the increase in reaction time in case of sudden braking of lead vehicle and the increase in the number of involuntary lane exceedances is higher than the one caused in the healthy control participants by the BAC=0.5% condition.

In conclusion, besides alcohol consumption (0.5%) obstructive sleep apnoea impairs some key parameters in driving performance. The results of the study indicated that OSAS may be a contributing factor to MVAs. Furthermore, CPAP treatment should be considered for OSAS patients. It remains to be investigated if CPAP is the most effective OSAS treatment.

1 INTRODUCTION
A large number of subjective (i.e., self-report) and objective (e.g., insurance or police records) studies have looked at the prevalence of Motor Vehicle Accidents (MVAs) for patients suffering from OSAS as compared to the general population (e.g., George, 1995; Maycock, 1996; Wu & Yan-Go, 1996). The majority of these studies have suggested that OSAS presents an increased risk factor for MVAs. However, the results obtained from these studies have been criticized due to the various confounding variables that were not controlled for (e.g., gender, age, driving experience etc.) and due to the possible biases that could have affected the results (i.e., informational, recall, and selection bias; cf., George, 2004).
In order to obtain a more accurate measure regarding the risk of MVAs for OSAS patients as compared to healthy participants, researchers have turned to experimental testing using various types of off-road driving simulators. Results from these studies have shown that patients with OSAS have an increased accident rate in driving simulation tests (e.g., Findley et al., 1989, 1995; George, Boudreau, & Smiley, 1996; Juniper et al., 2000; Mazza et al., 2005), estimated to be around two- to seven-times higher as compared to healthy participants (e.g., Horne & Reyner, 1999; George, 2004; George et al., 1987; Findley et al., 1989). It has also been reported that OSAS patients exhibit slower reaction times than controls in road obstacle avoidance, resulting in four times more object collisions than healthy participants (Findley et al., 1989). In addition, it has been demonstrated that OSAS patients perform poorer than controls in steering ability (referred to as “tracking error”; George et al., 1996; Juniper et al., 2000), with half of the patients being worse than any one control participant, and with some patients showing worse performance than healthy volunteers under the influence of alcohol (George et al., 1996). Finally, the research conducted to-date have concluded that the OSAS patients face an increased difficulty in sustaining attention while driving, thus exhibiting poorer performance and lower vigilance during experimental testing with driving in a monotonous highway route (e.g., George, Boudreau, & Smiley, 1996; Juniper et al., 2000; Turkington et al., 2001).

Overall, research findings strongly suggest that patients suffering from OSAS have a higher risk of having MVAs as compared to their healthy counterparts. The question that arises, therefore, is: “Should the OSAS patients be considered fit to drive?”. Given that driving is an essential part of everyday life for the majority of people, a series of treatments have been developed, in order to assist OSAS patients in driving and other daily functions.

Continuous Positive Airway Pressure (CPAP) represents the most commonly used treatment and it is considered to be the most effective one (Cassel et al., 1996; Yamamoto et al., 2000). Studies have shown that CPAP treatment can reduce the number of accidents in patients with OSAS, both in simulated driving (Findley et al., 1989) and in real-life situations (e.g., Cassel et al., 1996; Findley et al., 2000; George, Boudreau, & Smiley, 1997; Yamamoto et al., 2000). Specifically, studies have shown that regular use of CPAP improves self-reported (Cassel et al., 1996; Yamamoto et al., 2000) and objective MVA rates (Findley et al. 2000; George 2001). More importantly, research suggests that CPAP may effectively reduce the MVA risk of OSAS patients in experimental tests conducted in a simulated driving setting (e.g., Engleman et al., 1994; Findley et al., 1989; Note, however, that the task utilized in some of these studies was actually a choice reaction task that required sustained vigilance rather than a simulated driving task).

The past research reviewed here suggests that OSAS is a significant contributing factor to accidents affecting both the patients and other road users. If CPAP treatment improves driving performance, hence it contributes significantly to MVAs risk reduction. It should be taken into serious considerations that various studies focussing on OSAS patients and their driving performance have used diverse driving tasks, different simulators or tracks. Therefore generalisability issues are of major concern.

Another important limitation that can be identified in previous research is the issue of correct patient diagnosis and appropriate consideration of the circadian circle influence on participants’ performance. For example, in Orth et al.’s (2005) study, it was reported that testing was completed over different time periods (i.e., some tests took place in the morning and other at night) with a number of patients and healthy participants performing similarly in the driving task. This fact raises the concern whether the patients in this study were actually suffering from OSAS or not. On the same note, Turkington et al., 2004 did not include a control group in their study, thus one cannot accurately evaluate whether the patients’ performance, as compared to controls, was impaired or not. Finally, a major limitation noted
in past research concerns the choice of experimental methodology that may inadvertently have led to inaccurate or insufficient conclusions. For instance, Orth et al. reported null results in participant vigilance testing, while the opposite was reported in the Cassel et al. study, thus the choice of the attentional measure used could have been inappropriate. Similarly, Turkington et al.’s choice of very brief post- and pre- CPAP treatment time measurements could have failed to provide representative results of the CPAP effectiveness and therapeutic time course. Last but not least, Orth et al. utilized a simulator setting that required manual scoring by a technician, which could have led to possible recording errors, while the majority of simulated driving studies have only focused on the participants tracking error measurements, while ignoring the possible wide range of impairments that could be present in OSAS patients.

On the whole, research to-date identifies OSAS as a significant risk factor to MVAs and supports that treatment of OSAS using CPAP can reduce this risk. As yet, however, there are no generally accepted regulations within the Europe Union concerning driving licensing and OSAS. Thus, it seems pertinent that these regulations are established both for the benefit of the OSAS patients and the safety of all drivers.

In the present study, therefore, it was aimed to investigate the level of risk for MVAs for OSAS patients, while controlling for previous limitations, and to measure whether or not CPAP treatment can significantly reduce this risk. In order to accomplish this, it was compared the performance levels of CPAP-treated OSAS patients, untreated OSAS patients, and healthy control participants in a series of simulated driving and cognitive functioning tasks. In order to avoid pitfalls of previous research, careful consideration was taken in designing this study. Specifically, a representative sample of both male and female participants was recruited, so that the findings can be generalized in the OSAS population; this sample was required to complete a series of practice sessions, both in the simulator and in the cognitive tasks, in order to ensure familiarity with the experimental setting. All practice and experimental sessions were conducted at the same time of day, thus avoiding circadian influence on participant performance. Moreover, correct medical diagnosis was ensured by the collaboration with medical experts (patients had to be diagnosed with a hypopnoea index equal or larger than 10) and multiple simulated driving measures were recorded for each participant, in order to establish the whole range of OSAS driving impairment.

2 METHOD

2.1 Participants
In total, 31 male (50.3±14.2 yrs) and 5 female (38.8±12.1 yrs) participated in the study. OSAS patients were polysomnographically confirmed in order to be included in the study and only if their apnoea-hypopnoea index was above ten events h⁻¹. The OSAS patients were selected by the collaborating research doctor from a list of patients from the Centre of Air Medicine IASI. The healthy group was selected by advertisement and was matched to the OSAS group in terms of age and gender. The healthy group had no medical problems. Similarly, OSAS patients had no other medical problem apart from OSAS. Participants in both groups were active and experienced drivers, which was defined as having a driving license for at least 3 years and driving an annual distance of at least 10000 km.

Exclusion criteria for both groups were positive testing for alcohol (using the LifeLoc Technologies FC20 PORTABLE BREATH TESTER) or positive testing for Cocaine, Amphetamines, Methamphetamine, Opiates, Marijuana/Hashish and BZD (using the
Medimpex United, Inc. XALEX 6 Panel Multi Drug Urine Testing Kit). Written informed consent was obtained from all participants before testing.

Untreated OSAS patients were tested and then were re-tested after having used the CPAP treatment continuously for at least 7 days. Already treated OSAS patients were tested and were asked to stop the CPAP treatment for at least 7 days before being tested again. The healthy group consisted of 18 participants who were tested in two conditions, with BAC 0% and with BAC 0.5%, which is the legal limit for driving in Greece. The order of testing was counterbalanced within the healthy group. Tests were performed at the same time of day for each participant, in the afternoon between 14:00 and 17:00.

2.2 Design
The present study utilized a within- and between-participant design for the comparison of the OSAS and healthy experimental groups in question. There were two groups and four conditions in the experiment, OSAS treated - OSAS untreated and Healthy BAC 0% - Healthy BAC 0.5%.

2.3 Procedure
Participants were asked to arrive at HIT at the same time of day for both of their tests, between 14:00 and 17:00. All participants followed a familiarisation phase, so as to diminish learning effects. At their first appointment they completed an introductory questionnaire with demographic questions, after written informed consent was obtained. One copy of the informed consent was given to the participant. After both alcohol screening with breathalyser and urine drug screening were found negative, participants had to complete the following tasks at the driving simulator: a) perform a road tracking scenario for about 20 minutes in a highway environment maintaining a constant speed of 90 km/h and b) perform a car-following scenario for about 20 minutes in a highway environment maintaining a close but safe distance from the lead vehicle that was moving with a steady speed of 90 km/h. In random instances during the scenario, the vehicle ahead braked abruptly. The instructions given for the road tracking scenario were “Maintain a constant speed of 90 km/h and steady lateral position”. The instructions given for the car-following scenario were “Maintain a distance as low as possible but always safe to the lead vehicle”. The order of the two scenarios was counter-balanced among the two tests and among participants. After the simulator rides, the participants had to complete a series of neuropsychological tests (winTAP) on a PC. The laboratory TAP test of PsyTest and the following three tasks have been selected: a) Alertness test, which measures the reaction time (msec) to a target stimulus, b) Go-NoGo test, which measures the reaction time (msec), reacting selectively to one class of stimuli but not to others, and c) the auditory, visual and audiovisual divided attention task. Omissions and errors were recorded, respectively.

Before and after each simulator scenario and the neuropsychological tests participants were asked to rate their sleepiness level using the Karolinska Sleepiness Scale (KSS) (Åkerstedt and Gillberg, 1990). In addition, subjective assessments of mental effort per task and driving quality were, also, collected.

2.4 Statistical analysis
During the study, the following data were collected: a) raw data from the simulator, i.e. speed, lateral position, lateral acceleration, brake pedal position, accelerator pedal position, steering wheel angle, distance to lead vehicle, speed of lead vehicle, b) reaction times from the laboratory tests of cognitive functioning and data from the KSS. From the simulator data, it has been calculated the mean speed, the standard deviation of speed, the standard deviation of
lateral position, the standard deviation of lateral acceleration, the turning speed of the steering wheel, the standard deviation of the turning speed of the steering wheel, the number of lane exceedances, the percentage of total time that the lane exceedances lasted, the average and minimum headway to the lead vehicle, the standard deviation of this headway, the number of crashes to the lead vehicle, the reaction time to the lead vehicle braking, calculated as the time lapse from the lead vehicle braking initiation to either the release of the accelerator pedal or the stepping on the brake pedal.

To compare results between groups independent and paired sample t-tests were applied. Correlations between simulator, laboratory tests performance and KSS ratings were measured using the Spearman’s rank ($\rho$) correlation coefficient. In all cases, a significance level of $\alpha = .05$ was set.

3 RESULTS

Although, multiple comparisons have been carried out in order to investigate diverse types of effects of sleep syndrome and alcohol consumption, mostly significant findings are given according to the type of driven scenario. Firstly, lane tracking comparisons are presented, followed by car following results, and last neuropsychological findings and subjective assessments are presented.

3.1 Lane Tracking

OSAS patients had significantly higher Standard Deviation of Lateral Position (SDLP) recordings (m) compared to healthy controls on the monotonous motorway driving scenario ($p < .001$).

![Figure 1: Mean SDLP values per condition in lane tracking scenario](image)

However, no statistical significant differences were found on SDLP measurements between treated and untreated OSAS patients and between the control and alcohol consumption group (BAC = 0.5%) ($p > .05$). In addition, statistically significant differences
were found between control group participants in steering angle \((p < .037)\) and percentage \((\%)\) of time in lane exceedances \((p < .027)\).

![Mean percentage (%) of driving time spent in lane exceedances](image1)

Figure 2: Mean percentage (%) of driving time spent in lane exceedances

Sleep apnoea patients showed significantly higher deterioration compared to healthy controls. On the other hand, no significant improvement was revealed due to CPAP treatment in the lane tracking scenarios \((p > .05)\). Steering wheel speed difference (effect size) is much higher in the CPAP group than in 0.5% BAC group. This result shows that significance may not be of statistical interest, but the finding is, nonetheless, worth discussing.

![Within groups mean differences (Δ) in steering wheel speed (deg/sec)](image2)

Figure 3: Within groups mean differences (Δ) in steering wheel speed (deg/sec)
3.2 Car Following

No significant differences were found among groups on the number of crashes when the leading vehicle abruptly braked \((p > .05)\).

![Figure 4: Within groups mean differences (Δ) in number of crashes](image)

Yet the size of difference (fig. 4) shows a trend towards increase of number of crashes when healthy controls consume alcohol at 0.5% and, on the other hand, number of crashes decrease with CPAP treatment.

Within group comparisons yielded non significant findings \((p > .05)\). Nevertheless, statistically significant increase in lateral acceleration is noted in the untreated group compared to healthy participants (fig. 5) \((p < .001)\).
Moreover, as shown in figure 6, CPAP treated patients’ minimum headway was not much different when compared to minimum distance recorded in control group. On the contrary, the minimum headway in the alcohol group is significantly higher than both control and untreated groups ($p < .001$).
3.3 Neuropsychological tests (WinTAP)
Participants who consumed alcohol at BAC=0.5% were significantly less alert than the control group ($p=.044$).

![Figure 7: Mean reaction times (msec) per group across neuropsychological tests](image)

The alcohol group showed significantly lower mean reaction time (msec) in the divided visual attention task compared to the untreated OSAS patients ($p = .032$). No significant differences were found in number of omissions and errors ($p>.05$).

3.4 Subjective assessments
The Karolinska Sleepiness Scale (KSS) across the study conduction showed the same variations in both conditions. OSAS treated patients perceived sleepiness was lower compared to the ratings in the untreated condition, but not significantly so (fig. 8).

![Figure 8: KSS ratings for both treated and untreated OSAS patients throughout the study](image)

Subjective ratings of mental effort and quality of driving did not yield any differences across groups and conditions.
4 DISCUSSION

This study demonstrates that untreated OSAS patients’ driving performance is deteriorated compared to healthy control participants. On the other hand, driving under the influence of alcohol was not significantly deteriorated in key driving parameters. The chosen alcohol level may not be adequate in order to reveal significant deterioration in the parameters under investigation in this study.

As research focuses mainly on substances and alcohol misuse, this study aimed at investigating driving performance of OSAS patients and its relation to alcohol impairment. According to the findings, untreated OSAS patients with an apnea-hypopnea index > 10 show deterioration in driving performance and in laboratory test performance. Standard Deviation of Lateral Position (SDLP) is a reliable and sensitive index of measuring how well participants maintain their lateral position on the road. In relation to SDLP differences, OSAS patients demonstrated increased road tracking error, thus lower ability to control the lateral position of the vehicle compared to controls. Thus, deterioration in lateral maintenance of a vehicle, inevitably, is related to increase of risk of MVAs and near miss collisions.

While deteriorated OSAS patients’ overall driving performance was found, the effectiveness of CPAP treatment was not clearly evident in this study. Mean differences in steering wheel speed between the alcohol and the CPAP treated groups (non significant), may yield trends that could provide future hypotheses for further research into temporal effects of CPAP treatment.

The increase in the number of involuntary lane exceedances (lane tracking scenario) is higher than in the condition BAC=0.5, hence OSAS patients’ risk of accidents is shown to be high. Consequently this finding emphasizes the necessity of patients close collaboration with their physician in order to ensure safe driving. Deterioration findings are in accordance with current research and impose critical questions, especially for professional drivers.

Considerable limitations in the current study may involve learning effects, thus leading in to inconclusive results, particularly regarding the maintained alcohol level (0.5%). Previous research has demonstrated that 5 minutes familiarisation is adequate to plateau any learning confounding effect (Juniper et al., 2000). However, the differences in the driving simulators used in studies should be taken into account and on site demonstrators should rely on their own observations besides timelines.

This study encompassed objective, subjective and neuropsychological assessment of both alcohol intoxicated participants and OSAS patients. Additionally, no significant correlations were found between neuropsychological results and simulator driving parameters. It is not clear if the deterioration in neuropsychological testing could not be revealed due to the skills investigated not being impaired or because of non effectiveness of treatment. The latter remains to be investigated in future studies. Likewise, objective measurements did not correlate with subjective assessments of sleepiness, mental effort and driving quality. Perceived sleepiness, though, was lower in the CPAP treated group. This finding agrees with previous research on validity and sensitivity of KSS in behavioural assessment of sleepiness, and its role in CPAP effectiveness should be investigated further in simulated environments. With regard mental effort and driving quality self-assessments, it may be the case that participants reported the magnitude of mental effort and driving quality as an outcome of their tiredness during the study. The investigation of effectiveness of CPAP should additionally be applied in low to medium traffic simulated environments and not only in tiredness provoking scenarios.
REFERENCES


George, C. F. P. (2001). Motor vehicle collisions are reduced when sleep apnoea is treated with nasal CPAP. *Thorax, 56, 508-512.*


DRINKING AND DRIVING PROJECT IN GUANGXI

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Abstract:

The drinking and driving project in Guangxi is a four–year project with multi-sector participation. The project involves three cities in China:

- Nanning and Liuzhou in Guangxi province as intervention cities
- Changsha in Hunan province as the control city.

The project has gone through the process of a situational survey (baseline survey), intervention and evaluation:

- The situational survey (include both roadside survey and crash survey) helped to find out the nature and scope of problem related to drinking and driving in the three cities, as well as the issues (people, time and places) that should be the focus during the intervention.
- The intervention was developed using the findings of the baseline survey. It was carried out at the intervention cities with both components of a public education campaign and enhanced law enforcement. The purpose was to raise public awareness of the risk of drinking and driving behaviour, reduce prevalence of drinking and driving, as well as the number of related casualty crashes.
- The post-intervention survey helped to evaluate the effectiveness of the intervention and better understand the experiences and lessons learned from it.

The outcomes showed the success of the intervention. Nearly 75 percent of people interviewed in Nanning and 79 percent of people interviewed in Liuzhou aware of our public education campaign. And, the BAC positive rate in Nanning and Liuzhou was significantly decreased from 6.8 percent to 1.6 percent ($\chi^2=375.883$, df=1, p<0.001). On the contrast, the BAC positive rate in Changsha was increased from 3.1 percent to 4.4 percent ($\chi^2=12.109$, df=1, p<0.001).
1. **Background:**

There is a well-researched and documented causal link between drink driving in drivers and an increased risk of road traffic crash. The World Report on Road Traffic Injury Prevention highlights studies show that drivers who have been drinking have a much higher risk of involvement in crashes than those with no alcohol in their blood, and this risk grows rapidly with blood alcohol concentration (BAC). For motorcyclists, having a BAC over 0.05g/100ml has been estimated to increase crash risk by up to 40 times compared to having a zero BAC\(^1\).

Alcohol intoxication is a leading contributor to road traffic injuries and deaths in most countries. The European Commission estimated that at least one quarter of deaths (about 10,000) in road accident in the existing fifteen country of the European Union in the year 2000, were due to alcohol, at a cost of 10 billion Euros per annum\(^2\). In 2001, an estimated 41 percent of 42,116 fatalities were alcohol-related in USA, and about 21 percent of all drivers involved in fatal crashes were intoxicated\(^3\). In 1999, 15,786 road traffic fatalities and 300,000 injuries in USA were associated with alcohol use\(^4\). A series of hospital-based studies have shown that between 26% and 31% of non-fatally injured drivers are intoxicated in Africa\(^5\).

In China according to the statistics reports on road traffic fatalities and injuries, 3.06% (3368/109383) and 3.77% (3937/104372) of fatalities were related to drink-driving in 2002 and 2003, respectively\(^6\). The proportion of drink driving among road traffic fatalities is far lower than those in Sweden, the Netherlands and the United Kingdom (around 20%)\(^7\), but this is hypothesised as due to substantial under-reporting and underestimation in China.

In developed countries, there are comprehensive enforcement and penalty strategies to address drink-driving, such as random breathe testing (RBT) with high financial penalties, driving suspensions and even prison terms for those found to be exceeding legal thresholds. The implementation of those strategies was usually combined with public education campaigns\(^8\). 

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\(^{1}\) Source: World Report on Road Traffic Injury Prevention

\(^{2}\) Source: European Commission

\(^{3}\) Source: USA National Highway Traffic Safety Administration

\(^{4}\) Source: USA National Highway Traffic Safety Administration

\(^{5}\) Source: A series of hospital-based studies

\(^{6}\) Source: Statistics reports on road traffic fatalities and injuries in China

\(^{7}\) Source: Sweden, the Netherlands and the United Kingdom

\(^{8}\) Source: Comprehensive enforcement and penalty strategies
On May 31, 2004, General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China issued the GB19522—2004, in which the national standard for definitions of drink-driving and drunk driving was set up. According to the GB19522—2004, drivers with a BAC below 20mg% are sober, drivers with a BAC between 20mg % and 80mg% are driving under the influence (DUI) and those with a BAC in excess of 80mg% are driving with intoxicated (DWI). The Road Traffic Law of PR China, which is published on May 1, 2004, has indicated the punishment measures for drink-driving.

However, there were no previous studies to measure the association between alcohol and road traffic injuries and fatalities undertaken in China. In order to estimate the current situation of alcohol use among drivers, and the association with road traffic casualties, we started the project with conducting the epidemiological study the selected cities. A representative sample of motor vehicle drivers in the cities (Nanning, Liuzhou) in Guangxi Autonomous Region were studied during the phase I of the project. Guangxi was chosen due to the investigator’s links with this region and the willingness and interest of local authorities in this work. In addition, it was also planned to have a series of road safety intervention activities in Guangxi Autonomous Region by GRSP.

In order to have an objective understanding of the intervention effect, Changsha was selected as the blank control for comparison at the beginning of phase II. Changsha was selected because of its similarity to Nanning in number of vehicle fleet, population, numbers of road traffic crashes and related fatalities/injuries.

The Drinking & Driving Intervention in Guangxi (hereafter referred to as the Project) has been conducted from 2006 to 2009. There are three cities involved in the project:

- Nanning – the capital of Guangxi province
- Liuzhou – an important industrial city in Guangxi province
- Changsha – the capital of Hunan province.

Nanning and Liuzhou were selected as the intervention cities for the project, while Changsha was selected as the control city.

The Project was divided into two phases:

- phase I – baseline survey (August 2006 to July 2007)
• phase II - the intervention (August 2007 to November 2008) and evaluation (December 2008 to September 2009).

The baseline survey was included both roadside and crash surveys. The roadside surveys were carried out during December 2006 to March 2007 in Nanning and Liuzhou, it was during Feb.- March 2008 in Changsha; the crash survey was carried during December 2006 to July 2007 in Nanning and Liuzhou, it was during March to June 2008 in Changsha (The snow disaster in January 2008 had a strong impact on the time period of roadside and crash baseline surveys in Changsha). This research was focused on accurately determining the prevalence of drinking and driving in a representative and random sample of drivers in Nanning, Liuzhou and Changsha as well as determining the proportion of crashes that were associated with alcohol intoxication.

The intervention phase included two components, which were public education and enforcement. It was conducted in three stages – preparation, implementation and evaluation. During the implementation time period (May to Nov. 2008), two rounds of a public education campaign and two rounds of an enhanced enforcement were carried out, in order to reduce both prevalence and proportion of crashes related to drinking and driving.

The post-intervention survey was carried out during December 2008 to July 2009 in both intervention and control cities. For the before/after data analysis, both roadside and crash surveys were repeated at the post-intervention.

The project was financially supported by the Global Road Safety Initiative (GRSI). Project partners include:

• World Health Organization (WHO)
• Global Road Safety Partnership (GRSP)
• Health Human Resource Development Center (HHRDC) of the Ministry of Health (MOH), P.R. China
• Clarity Public Relations (the P.R. company)
• Guangxi Institute of Occupational Health
• Nanning Municipal Center for Disease Control and Prevention (Nanning CDC)
• Nanning Traffic Management Bureau
2. Objectives:

- To understand the actual scale of the problem of alcohol impaired driving in both intervention and control cities;
- To reduce prevalence of drinking and driving in the intervention cities (Nanning and Liuzhou);
- To reduce numbers of casualty crashes related to drinking and driving in the intervention cities (Nanning and Liuzhou);
- To improve public awareness about the importance of road safety as well as the risks of drinking and driving.
- To increase knowledge of drivers and general public about drinking and driving related laws and regulations.
- To assess the effectiveness of the intervention.

3. Methods:

✓ Roadside survey

A multi-stage sample selection method was adopted for both the baseline survey and post-intervention survey. Motor vehicle drivers in the three cities (both automobiles and motorcycles) at different survey locations were randomly stopped for a breath test and questionnaire interview in the high-risk periods of alcohol related crashes in the afternoon (1:00 - 5:00 p.m.) and evening (8:00p.m. - 12:00 a.m.). The survey was conducted during workdays, weekends and holidays (Chinese New Year). The sample size design was for at least 4800 drivers (1600 at workdays, 1600 at weekends and 1600 at holidays) in each city.

23 checkpoints in Nanning, 21 in Liuzhou and 26 in Changsha including urban, suburban and rural areas were chosen for the baseline survey before the intervention, while 31 in Nanning, 21 in Liuzhou and 32 in Changsha were chosen for the post-intervention survey. The locations
chosen before and after the intervention were basically the same. These chosen locations met all requirements of a roadside survey, such as having sufficient traffic density and enough space for parking, no opportunity for vehicles to turn off at initial sighting of the checkpoint, and good lighting condition for evening survey.

The drivers were randomly stopped by the traffic police officers for a breath test (a second breath test will be taken after 20 minutes if the driver’s BAC was exceeded the lowest legal limit); meanwhile, an interview was given to the stopped drivers who agreed to accept it. The survey group at each checkpoint includes at least 3 traffic police officers and 3 investigators. The traffic police officers were in charge of traffic management, intercepting vehicles and measuring breath alcohol content. The investigators were responsible for recording the observed information (such as gender of the drivers, the status of seat belt wearing, etc.) and conducting the interview. A questionnaire was designed to understand the knowledge level of the drivers on drinking and driving related law, their attitude toward drinking and driving and the status of law enforcement in the three cities.

Epidata 3.1 software was used for the data entry procedure. To ensure the accuracy of data entry, double-entry method was adopted. Each questionnaire was entered by two staff separately, then the check function of EpiData3.0 was applied to compare the two matrix data files from the double entry. If any difference was found, the staff was to check the original questionnaire and make corresponding revisions. Data was then exported to SPSS 11.5 statistical software packages for cleaning, management and analysis.

Traffic Crash survey
It was carried out at both baseline survey and post-intervention survey in the three cities. All road traffic crashes (involving a motor vehicle) included in the study were:
a) the crashes occurred on a public road of those selected districts/counties in the period of study;
b) the crashes resulting in at least one person seriously injured or died from their injuries (within 7 days). 'Serious injury' was defined as major fracture, caniocerebral trauma or other severe injuries that should involve hospitalization.

The Traffic Police Crash Handling Sections of the selected districts/counties undertook the investigation by completing questionnaires developed for this study. The main items of the
questionnaire include date and time of crashes, number of vehicles involved, number of killed and injured persons, circumstances of the crash, characteristics of drivers and victims.

Blood samples were collected by nurses under the supervision of local traffic police officials. The concentrations of blood samples were tested at designated laboratories of the three cities. Copies of BAC testing results were provided by official designated organizations. The questionnaires and BAC results were examined and collected from the traffic police offices of the district/county by investigators in the collaborating agencies from the local health sector. The local investigators were responsible for checking/collecting the questionnaires and BAC result reports from the traffic police officers regularly.

The designed sample size was no less than 80 cases in each city.

✓ Public education program - Information campaign

Clarity Public Relations was selected as the PR company to assist in designing material for the campaign and implementing the public education activities. The project logo, theme slogans, the project Ambassador and a series of promotional items were designed for the public education campaign. Two rounds of public education campaigns were carried out during May to November 2008 in Nanning and Liuzhou. The activities included:

- media programs via TV, radio, newspapers and the Internet
- bus body and roadside advertisements
- promotional items delivery(refer to examples listed blow).
Two rounds of enhanced law enforcement were carried out during May to November 2008 in the cities of Nanning and Liuzhou. Unlike the method of random sampling used in the surveys, the enforcement activities in the two rounds of enforcement focused on designated time locations and suspicious drivers. The targeted areas included major junctions, nightspots, restaurants and bars/entertainment centers. Police roadblocks and alarm lights were used at the checkpoints to achieve maximum visual effect. Large numbers of police and police vehicles were deployed and the checkpoints were frequently changed during the enforcement activities in order to:

a) Create the perception from the driving population that “if you drink and drive, you will be caught at any time, any where”.

b) Remind all passing drivers, as well as other road users, that drinking and driving is an illegal and immoral behaviour – if you offend you will be subject to legal penalty.

c) Along with the public education campaign, increase the commitment from the driving population to the message that “if you drink, do not drive and if you drive, do not drink”.

Enhanced Law Enforcement
4. **Intervention Activities:**

During the 6-month implementation of the intervention (May to November 2008), two rounds of the public education campaign and two rounds of enhanced law enforcement were carried out in both Nanning and Liuzhou:

- **1st round of public education campaign**: May to July
- **1st round of enhanced law enforcement**: June to July
- **2nd round of public education campaign**: August to November
- **2nd round of enhanced law enforcement**: September to October

✓ **Public education campaign**

A. **Media Program**

- Four major formats of mass media, namely TV, radio, newspapers and the Internet, were utilized in the campaign, along with SMS for the enhanced effect of publicity.
- There was significant publicity about the background of the Project, the rules and regulations regarding drinking and driving, and the physical impact of alcohol. This was released in the form of “Quiz-Gift” questions through major forms of mass media.
- There was extensive news coverage for the follow-up reports, including the Project launch events in the two cities, traffic police involvement in the law enforcement, volunteers’ contributions in promotional item delivery, quizzes rewards and interviews with experts.

B. **Bus body and Roadside Advertisements**

- 13 buses in Nanning, and 18 buses in Liuzhou were chosen for the bus body advertisement in the campaign. The bus routes covered densely populated area from all directions of the city.
✓ 75 small-sized road signs were produced and put up on major roads and intersections in Nanning. In Liuzhou 7 large-sized road signs were erected on the major roads and streets during the campaign.

C. Distribution of Promotional Items

Distribution of promotional items was one of the integral parts of the public education campaign. Led by CDC in both cities, distribution work was mainly carried out by volunteers with the support of local traffic police and transport agencies.
The following chart lists the relevant information concerning distribution of promotional items in Nanning and Liuzhou during May to November 2008:

<table>
<thead>
<tr>
<th>Items</th>
<th>Distribution Spots</th>
<th>Nanning (PCS)</th>
<th>Liuzhou (PCS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Target</td>
<td>%</td>
</tr>
<tr>
<td>Posters</td>
<td>Communities and Restaurants</td>
<td>4,320</td>
<td>4,376</td>
</tr>
<tr>
<td>Table Displays</td>
<td>Restaurants and Bars</td>
<td>6,400</td>
<td>6,400</td>
</tr>
<tr>
<td>Cup-mats</td>
<td>Restaurants and Bars</td>
<td>6,936</td>
<td>7,000</td>
</tr>
<tr>
<td>Vehicle Stickers</td>
<td>Vehicles, Gas Stations and Parking Lots</td>
<td>38,151</td>
<td>80,000</td>
</tr>
</tbody>
</table>

D. *Exhibition Boards*

16 exhibition boards were produced for the campaign (8 for Nanning and 8 for Liuzhou). They were displayed in turn at the halls of vehicle administration departments and bus terminals within Nanning and Liuzhou to promote the drinking and driving related laws and relevant information.

E. *DVD Films*

Two short DVD films were designed for the public education campaign. They were released to the general public via TV/radio programs and cable TV system/net in public places, such as in the Vehicle Registration Office, the terminals for long distance bus, municipal government owned buildings in the two cities (Nanning and Liuzhou), as well as on the song-ordering systems in 56 major Karaoke bars of Nanning during the break time.
**Enhanced Law Enforcement**

**A. Nanning**

A total of 14 consolidated city level law enforcement activities were carried out by the Nanning Traffic Police during June to July and September to October 2008. They were conducted at 30 random check points covering six districts. The information below shows the special efforts made by the Nanning Traffic Police during the 2 rounds of enforcement:

<table>
<thead>
<tr>
<th></th>
<th>Traffic Police (persons-times)</th>
<th>Checkpoint Equipment</th>
<th>Drivers Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Breath Test Equipment</td>
<td>Police Vehicles</td>
</tr>
<tr>
<td><strong>2nd round law enforcement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept.</td>
<td>520</td>
<td>14</td>
<td>260</td>
</tr>
<tr>
<td>Oct.</td>
<td>390</td>
<td>16</td>
<td>234</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>910</strong></td>
<td><strong>30</strong></td>
<td><strong>494</strong></td>
</tr>
<tr>
<td><strong>1st round law enforcement</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>253</td>
<td>13</td>
<td>114</td>
</tr>
<tr>
<td>July</td>
<td>512</td>
<td>39</td>
<td>284</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>765</strong></td>
<td><strong>52</strong></td>
<td><strong>398</strong></td>
</tr>
</tbody>
</table>
B. Liuzhou

The law enforcement activities in Liuzhou were somewhat different from the ones in Nanning. Instead of the consolidated city level activities, the law enforcement activities in Liuzhou were conducted on a regular day-to-day basis in four different districts. In total there were 25 checkpoints scattered throughout the city. The information below showed the special efforts made by the Liuzhou Traffic Police during the two rounds of enforcement.

<table>
<thead>
<tr>
<th></th>
<th>Checkpoint Staff</th>
<th>Checkpoint Equipment</th>
<th>Drivers Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traffic police</td>
<td>Traffic Assistants</td>
<td>Breath Test Equipment</td>
</tr>
<tr>
<td>2 Round Law Enforcement</td>
<td>Sep 161</td>
<td>390</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Oct 150</td>
<td>318</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Total 311</td>
<td>708</td>
<td>168</td>
</tr>
<tr>
<td>1st Round Law Enforcement</td>
<td>Jun 63</td>
<td>156</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Jul 84</td>
<td>194</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Total 147</td>
<td>350</td>
<td>83</td>
</tr>
</tbody>
</table>

5. Result:

According to the GB19522—2004 issued by General Administration of Quality Supervision, Inspection and Quarantine of China, we divided the legal BAC limits into four categories for the study:

A) No alcohol (0 mg%)
B) Low BAC (below 20mg%)
C) Drink driving (20-80mg%)
D) Drunk driving (over 80mg%)
Roadside survey

The roadside survey is made of two components: random breath testing and questionnaire interview. The following is the main findings from the baseline (before) and post-intervention (after) surveys in the three cities:

✓ Total drivers intercepted: 32,101
  - BAC positive (BAC >0): 1,289 (4.0%)
  - BAC > 20mg: 892 (2.8%)
    - 20mg%≤BAC<80mg % 707 (2.2%)
    - BAC≥80mg % 185 (0.6%)
  - The highest BAC found: 413mg

✓ Type of vehicles intercepted:

<table>
<thead>
<tr>
<th></th>
<th>Drivers tested (BAC&gt;0)</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink-drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td>%</td>
<td>number</td>
<td>%</td>
</tr>
<tr>
<td>motorcycle</td>
<td>8,319</td>
<td>25.9</td>
<td>272</td>
<td>3.3</td>
</tr>
<tr>
<td>car</td>
<td>23,217</td>
<td>72.3</td>
<td>1,009</td>
<td>4.3</td>
</tr>
<tr>
<td>truck</td>
<td>565</td>
<td>1.8</td>
<td>8</td>
<td>1.4</td>
</tr>
<tr>
<td>total</td>
<td>32,101</td>
<td>100</td>
<td>1,289</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Statistical analysis showed that car drivers had the highest BAC positive rate ($\chi^2 = 28.492$, df = 2, $p <0.001$), and drink-drive rate ($\chi^2 = 23.228$, df = 2, $p <0.001$), followed by the motorcycle drivers; while truck drivers had the lowest rate. For drunk driving, the car driver's drunk driving rate was higher than that of motorcycle ($\chi^2 = 14.745$, df = 1, $p = 0.001$), while there was no statistically significance between the rate of drunk driving of motorcycle and truck drivers, which can be considered no difference between the two ($\chi^2 = 0.093$, df = 1, $p = 0.760$).
Drivers intercepted at different time:

<table>
<thead>
<tr>
<th></th>
<th>Drivers tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink-drivers (20≤BAC&lt;80)</th>
<th>Drunk-drivers (BAC≥80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>%</td>
<td>number</td>
<td>%</td>
<td>number</td>
</tr>
<tr>
<td>day</td>
<td>13,798</td>
<td>43.0</td>
<td>264</td>
<td>1.9</td>
</tr>
<tr>
<td>night</td>
<td>18,297</td>
<td>57.0</td>
<td>1,025</td>
<td>5.6</td>
</tr>
<tr>
<td>total</td>
<td>32,095</td>
<td>100</td>
<td>1,289</td>
<td>4.0</td>
</tr>
<tr>
<td>workdays</td>
<td>12,776</td>
<td>39.8</td>
<td>454</td>
<td>3.6</td>
</tr>
<tr>
<td>weekends</td>
<td>11,562</td>
<td>36.0</td>
<td>499</td>
<td>4.3</td>
</tr>
<tr>
<td>Chinese New Year</td>
<td>7,761</td>
<td>24.0</td>
<td>336</td>
<td>4.3</td>
</tr>
<tr>
<td>total</td>
<td>32,099</td>
<td>100</td>
<td>1,289</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The chi-square test analysis showed that at night the drivers’ BAC positive rate ($\chi^2 = 277.035$, $df = 1$, $p <0.001$), drink driving rate ($\chi^2 = 180.253$, $df = 1$, $p <0.001$), and drunk driving rates ($\chi^2 = 63.465$, $df = 1$, $p <0.001$) were higher than that during the day.

There was no statistically significance between the rate of BAC positive and drink driving between weekends and Chinese New Year, which can be considered no difference between the two (BAC positive rate: $\chi^2=11.763$, df=2, $p=0.003$; drink driving rate $\chi^2=13.649$, df=2, $p=0.001$), but were higher than that of workdays. For drunk driving, There was no statistically significance among workdays, weekends and Chinese New Year, which can be considered no difference among the three time period ($\chi^2=0.301$, df=2,p=0.860).

Gender distribution:

<table>
<thead>
<tr>
<th></th>
<th>Drivers tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink-Drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>%</td>
<td>number</td>
<td>%</td>
<td>number</td>
</tr>
<tr>
<td>male</td>
<td>28,775</td>
<td>89.6</td>
<td>1,251</td>
<td>4.3</td>
</tr>
<tr>
<td>female</td>
<td>3,325</td>
<td>10.4</td>
<td>38</td>
<td>1.1</td>
</tr>
<tr>
<td>total</td>
<td>32,100</td>
<td>100</td>
<td>1,289</td>
<td>4.0</td>
</tr>
</tbody>
</table>
The chi-square test showed male drivers had higher rates of BAC positive ($\chi^2=79.418$, df=1, $p<0.001$) than female drivers.

Drink driving ($\chi^2=44.138$, df=1, $p<0.001$) and drunk driving ($\chi^2=19.315$, df=1, $p<0.001$) than female drivers.

✓ Age distribution:

<table>
<thead>
<tr>
<th></th>
<th>Drivers tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink - Drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
<td>%</td>
<td>number</td>
<td>%</td>
</tr>
<tr>
<td>≤24</td>
<td>1,126</td>
<td>3.5</td>
<td>18</td>
<td>1.6</td>
</tr>
<tr>
<td>25-34</td>
<td>10,519</td>
<td>32.8</td>
<td>331</td>
<td>3.1</td>
</tr>
<tr>
<td>35-44</td>
<td>12,515</td>
<td>39.1</td>
<td>533</td>
<td>4.3</td>
</tr>
<tr>
<td>≥45</td>
<td>7,873</td>
<td>24.6</td>
<td>405</td>
<td>5.1</td>
</tr>
<tr>
<td>total</td>
<td>32,033</td>
<td>100</td>
<td>1,287</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The chi-square test showed the older the drivers, the higher the BAC positive rate ($\chi^2=65.576$, df=3, $p<0.001$) and drink driving rate ($\chi^2=47.794$, df=3, $p<0.001$) were. Whilst for drunk driving, there were no statistically significance for the comparison of population ($\chi^2=4.093$, df=3, $p=0.252$) and the comparison of every age group, showing no difference in drunk driving rate among different age groups.

✓ Driving with Passengers:

According to the survey records, 13,880 vehicles tested (43.7%) were without passengers, of which 474 (3.4%) were proven BAC positive. 17,897 vehicles tested were with passengers, of which 795 (4.4%) were proven BAC positive. Thus, the conclusion was drivers with passengers in car had a higher drink driving rate than drivers drove alone ($\chi^2 = 21.510$, df = 1, $p <0.001$).
✓ BAC Positive Rate by Subgroups:

Comparisons of the Results of Baseline & Post-intervention Roadside Survey

The following tables provide the result comparison of random breath testing at the baseline survey (before) and post-intervention (after) in the three cities:

a) Nanning

<table>
<thead>
<tr>
<th>Type of Drivers</th>
<th>Number of Drivers Tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink - Drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
<th>Illegal Drink-drivers≥20mg %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>835</td>
<td>23</td>
<td>23</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>Cars</td>
<td>4287</td>
<td>87</td>
<td>178</td>
<td>33</td>
<td>211</td>
</tr>
<tr>
<td>Trucks</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub-total</td>
<td>5127</td>
<td>110</td>
<td>201</td>
<td>36</td>
<td>237</td>
</tr>
<tr>
<td>Post-intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>2639</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Cars</td>
<td>2706</td>
<td>3</td>
<td>17</td>
<td>7</td>
<td>24</td>
</tr>
<tr>
<td>Trucks</td>
<td>65</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub-total</td>
<td>5410</td>
<td>11</td>
<td>27</td>
<td>12</td>
<td>39</td>
</tr>
</tbody>
</table>
Compared with the baseline survey, the outcome of the post intervention survey in Nanning showed the number of drink-drivers was reduced from 201 to 27; the number of drunk-drivers was reduced from 36 to 12, and the number of illegal drink drivers was reduced from 237 to 39.

b) **Liuzhou**

<table>
<thead>
<tr>
<th>Type of Drivers</th>
<th>Number of the Drivers Tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink - Drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
<th>Illegal Drink-drivers≥20mg%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>2698</td>
<td>51</td>
<td>97</td>
<td>15</td>
<td>112</td>
</tr>
<tr>
<td>Cars</td>
<td>2684</td>
<td>82</td>
<td>116</td>
<td>19</td>
<td>135</td>
</tr>
<tr>
<td>Trucks</td>
<td>176</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sub-total</td>
<td>5558</td>
<td>135</td>
<td>214</td>
<td>34</td>
<td>248</td>
</tr>
<tr>
<td>Post-intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td>2104</td>
<td>15</td>
<td>13</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>Cars</td>
<td>3411</td>
<td>25</td>
<td>41</td>
<td>20</td>
<td>61</td>
</tr>
<tr>
<td>Trucks</td>
<td>79</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub-total</td>
<td>5594</td>
<td>40</td>
<td>54</td>
<td>26</td>
<td>80</td>
</tr>
</tbody>
</table>

Compared with the baseline survey, the outcome of the post intervention survey in Liuzhou showed the number of drink-drivers was reduced from 214 to 54; the number of drunk-drivers was reduced from 34 to 26 and the number of illegal drink drivers was reduced from 248 to 80.

c) **Changsha - the control city**

<table>
<thead>
<tr>
<th>Type of Drivers</th>
<th>Number of the Drivers Tested</th>
<th>BAC positive drivers (BAC&gt;0)</th>
<th>Drink - Drivers (20mg%≤BAC&lt;80mg %)</th>
<th>Drunk-drivers (BAC≥80mg %)</th>
<th>Illegal Drink-drivers≥20mg%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorcycle</td>
<td>39</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>car</td>
<td>5218</td>
<td>62</td>
<td>94</td>
<td>9</td>
<td>113</td>
</tr>
<tr>
<td>truck</td>
<td>125</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub-total</td>
<td>5382</td>
<td>63</td>
<td>94</td>
<td>9</td>
<td>113</td>
</tr>
<tr>
<td>post intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorcycle</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>car</td>
<td>4911</td>
<td>35</td>
<td>114</td>
<td>67</td>
<td>181</td>
</tr>
</tbody>
</table>

412
While in the control city Changsha, the outcome of the post intervention survey showed number of
drink-drivers was increased from 94 to 114 and the number of drunk-drivers was increased from 9 to
68 and the number of illegal drink drivers was increased from 113 to 182. This is partly because the
snow disaster impact to the baseline survey in Changsha.

The following tables provide the before/after data comparison between the intervention cities
(Nanning and Liuzhou) and the control city (Changsha) on some of the information obtained from
the questionnaire interview at the baseline survey (before) and post-intervention survey (after).

## Before and After Data Comparison - Awareness Rate of the legal BAC limit in China

<table>
<thead>
<tr>
<th>City</th>
<th>Intervention</th>
<th>People Interviewed</th>
<th>Awareness Rate</th>
<th>Chi Square Test</th>
<th>Correct Answer Rate</th>
<th>Chi Square Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>%</td>
<td></td>
<td>Number</td>
<td></td>
</tr>
<tr>
<td>Nanning</td>
<td>Before</td>
<td>5,127</td>
<td>694</td>
<td>13.5</td>
<td>989.380, df=1, p&lt;0.001</td>
<td>205</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>5,407</td>
<td>2,214</td>
<td>40.9</td>
<td>179.508, df=1, p&lt;0.001</td>
<td>589</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>Before</td>
<td>5,531</td>
<td>871</td>
<td>15.7</td>
<td>8.696, df=1, p=0.003</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>5,589</td>
<td>997</td>
<td>17.8</td>
<td>17.606, df=1, p&lt;0.001</td>
<td>463</td>
</tr>
<tr>
<td>Changsha</td>
<td>Before</td>
<td>5,345</td>
<td>467</td>
<td>8.7</td>
<td>30.257, df=1, p&lt;0.001</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>After</td>
<td>5,013</td>
<td>603</td>
<td>12.0</td>
<td>14.249, df=1, p&lt;0.001</td>
<td>151</td>
</tr>
</tbody>
</table>
Before and After Data Comparison—Stopped by the Traffic Police for BAC Checking in Past Two Years

<table>
<thead>
<tr>
<th>city</th>
<th>intervention</th>
<th>People interviewed</th>
<th>Stopped for BAC Checking</th>
<th>chi square test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>number</td>
<td>%</td>
</tr>
<tr>
<td>Nanning</td>
<td>before</td>
<td>5,115</td>
<td>694</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,401</td>
<td>1,004</td>
<td>18.6</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>before</td>
<td>5,535</td>
<td>1,369</td>
<td>24.7</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,586</td>
<td>2,570</td>
<td>46.0</td>
</tr>
<tr>
<td>Changsha</td>
<td>before</td>
<td>5,351</td>
<td>747</td>
<td>14.0</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,019</td>
<td>650</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Before and After Data Comparison – Perceived Possibility of Being Caught by Traffic Police for Drink Driving

<table>
<thead>
<tr>
<th>city</th>
<th>intervention</th>
<th>People interviewed</th>
<th>Perceived Possibility of Being Caught</th>
<th>chi square test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>number</td>
<td>%</td>
</tr>
<tr>
<td>Nanning</td>
<td>before</td>
<td>5,127</td>
<td>4,033</td>
<td>78.7</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,407</td>
<td>2,619</td>
<td>48.4</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>before</td>
<td>5,532</td>
<td>3,838</td>
<td>69.4</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,589</td>
<td>3,825</td>
<td>68.4</td>
</tr>
<tr>
<td>Changsha</td>
<td>before</td>
<td>5,347</td>
<td>2,290</td>
<td>42.8</td>
</tr>
<tr>
<td></td>
<td>after</td>
<td>5,011</td>
<td>2,183</td>
<td>43.6</td>
</tr>
</tbody>
</table>

Traffic crash survey

Altogether 733 crashes and 1,040 drivers were investigated in Nanning, Liuzhou and Changsha during the baseline and post-intervention surveys. 505 of the 1040 drivers were blood tested during the two surveys. Although it was requested that all drivers who involved the severe crash to take the blood test, it is difficult in practice for the traffic polices to request the drivers who had no suspicion of drinking and driving to provide the blood sample. Therefore, some of the drivers received the breath test instead. The following tables show the number of crashes investigated in three cities before and after intervention.
Among 733 crashes investigated, 535 were non-alcohol related. Among the 198 alcohol related crashes, 30 (4.1%) crashes were drivers with low BAC (0<BAC<20mg %), 25(3.4%) were with drivers drink driving, 143 (19.5%) were with drivers drunk driving. The total alcohol related crashes accounted for 22.9% of the total investigated crashes.

The following three tables describe the results of the baseline (before) and post-intervention surveys at the three cities:

a) Nanning

<table>
<thead>
<tr>
<th>Nanning</th>
<th>Crashes Investigated</th>
<th>Drivers investigated</th>
<th>BAC20+ drivers</th>
<th>Alcohol involved crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Numbers %</td>
<td>Numbers %</td>
<td>Numbers %</td>
<td></td>
</tr>
<tr>
<td>Base line Survey</td>
<td>167</td>
<td>262</td>
<td>46</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>25.7</td>
<td></td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Post-intervention</td>
<td>185</td>
<td>281</td>
<td>41</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>20.5</td>
<td></td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

Among 733 crashes investigated, 535 were non-alcohol related. Among the 198 alcohol related crashes, 30 (4.1%) crashes were drivers with low BAC (0<BAC<20mg %), 25(3.4%) were with drivers drink driving, 143 (19.5%) were with drivers drunk driving. The total alcohol related crashes accounted for 22.9% of the total investigated crashes.

The following three tables describe the results of the baseline (before) and post-intervention surveys at the three cities:

a) Nanning

<table>
<thead>
<tr>
<th>Nanning</th>
<th>Crashes Investigated</th>
<th>Drivers investigated</th>
<th>BAC20+ drivers</th>
<th>Alcohol involved crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Numbers %</td>
<td>Numbers %</td>
<td>Numbers %</td>
<td></td>
</tr>
<tr>
<td>Base line Survey</td>
<td>167</td>
<td>262</td>
<td>46</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>25.7</td>
<td></td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>Post-intervention</td>
<td>185</td>
<td>281</td>
<td>41</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>20.5</td>
<td></td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>
b) Liuzhou

<table>
<thead>
<tr>
<th>Liuzhou</th>
<th>Crashes Investigated</th>
<th>Drivers investigated</th>
<th>BAC20+ drivers</th>
<th>Alcohol involved crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base line Survey</td>
<td>100</td>
<td>144</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-intervention</td>
<td>80</td>
<td>106</td>
<td>24</td>
<td>23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Changsha</th>
<th>Crashes Investigated</th>
<th>Drivers investigated</th>
<th>BAC20+ drivers</th>
<th>Alcohol involved crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base line Survey</td>
<td>101</td>
<td>137</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-intervention</td>
<td>100</td>
<td>110</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

It can be clearly seen that after 2 rounds of enhanced enforcement by the traffic police combined with 2 rounds of public educations campaigns, the number of illegal drink drivers involved in the crashes was reduced from 46 to 41 in Nanning and 50 to 24 in Liuzhou. The numbers of alcohol related crashes were reduced from 43 to 38 in Nanning and 48 to 23 in Liuzhou. On the contrary, in the control city of Changsha, where there was no intervention activities taken place, the number of illegal drink drivers involved in the crashes was increased from 3 to 13 and the numbers of alcohol related crashes were increased from 3 to 13.
The following bar charts show the difference made by the intervention on the rates of alcohol related severe crashes and drink drivers involved in the crashes in the three cities:

### Severe Crashes Related to Alcohol (%)

- **Nanning**: Pre-intervention 25.7%, Post-intervention 20.5%
- **Liuzhou**: Pre-intervention 48%, Post-intervention 28.8%
- **Changsha**: Pre-intervention 3%, Post-intervention 13%

### Proportion of the Drink-Drivers Involved in the Severe Crashes (%)

- **Nanning**: Pre-intervention 17.6%, Post-intervention 14.6%
- **Liuzhou**: Pre-intervention 34.5%, Post-intervention 22.6%
- **Changsha**: Pre-intervention 2.2%, Post-intervention 10.9%
• *Project Awareness Survey*

In order to assess the public awareness of the Project and to find out how the public got to know about the Project in Nanning and Liuzhou, two project awareness surveys were carried out in both cities. One was in late July (after the 1st round of the campaign); the other one was in mid-December 2008 (after the 2nd round of the campaign). The surveys were conducted on a random sample basis by inviting passers-by to fill in the questionnaire forms on the spot. The interviewees were restricted to the local residents in both cities. The table below shows the outcome of the two surveys.

<table>
<thead>
<tr>
<th>City</th>
<th>People interviewed - 1st round</th>
<th>People claim aware - 1st round</th>
<th>Project awareness Rate (%) – 1st round</th>
<th>People interviewed - 2nd round</th>
<th>People claim aware – 2nd round</th>
<th>Project awareness Rate (%) – 2nd round</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanning</td>
<td>320</td>
<td>103</td>
<td>32.1</td>
<td>321</td>
<td>240</td>
<td>74.8</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>348</td>
<td>188</td>
<td>54</td>
<td>376</td>
<td>295</td>
<td>78.5</td>
</tr>
</tbody>
</table>

6. **Discussion and Conclusions:**

Drinking and driving is a leading contributor to road traffic injuries and deaths in most countries. In most high-income countries about 20 percent of fatally injured drivers have a blood alcohol concentration (BAC) in excess of the legal limit. In contrast, studies in low and middle income countries have shown that between 33 percent and 69 percent of fatally injured drivers and between 8 percent and 29 percent of non-fatally injured drivers had consumed alcohol before their crash.¹⁰

Drinking and driving is also considered as one of the major risk factors on the road in China as well. The Chinese Government is paying more and more attention to the issue and has launched many different levels of anti-drinking and driving interventions during recent years. However, the following two characteristics make this project unique and different from other government interventions:
a) The project involved multi-sector cooperation with a wide range of partners, which included national and local government agencies, academic institutions, private sector and international agencies. The local partners (the traffic police and representatives from the health sector) in the cities of Nanning, Liuzhou and Changsha played a crucial role to the success of the project and the strengths of each partner were fully utilised in the project.

b) International good practice was adapted and a systematic/scientific method was used. This is the first of this kind of project to follow the international good practice in the Drinking and Driving Manual in China. Evidence based decision making and the process and outcome evaluations conducted during the intervention are the highlights of the project. The intervention activities were designed taking into account the findings of baseline survey, which made them more targeted and more effective. The evaluations provided a clear picture of whether or not the intervention implemented as planned and whether or not the actions taken in the intervention were effective. Both the experience gained and lessons learned from the project will be shared with the relevant stakeholders and hopefully to be used as reference for similar projects in the future.

The outcomes of the surveys have shown the effectiveness of the intervention. The drinking and driving behaviour in the intervention cities (Nanning and Liuzhou) has been greatly reduced, while it increased in the control city (Changsha). Through the two rounds of public education campaign, the general public and drivers in Nanning and Liuzhou began to realize that “drinking and driving is an illegal and immoral behaviour to the society”.

It is acknowledged that the six months of implementation of the intervention is too short for changing public attitudes and behaviours, and this was also shown from the results of the questionnaire interview, as well as the from result of our crash surveys. Raising public awareness requires unremitting efforts by relevant stakeholders of society, especially with the support from government. Continuous robust law enforcement in combination with repeated public education campaigns are a must to prevent drink-driving. It is hoped that this pilot project has planted a “seed” to encourage greater attention to the issue from government and the relevant agencies, and that it has raised public awareness of the problem. It is also hoped that more and more drivers will realize the risks of drink-driving and will make the commitment to “if you drink, do not drive; if you drive, do not drink!” So that, the ultimate goal of reducing the number of casualty crashes related to drinking and driving will be achieved in the future.
Reference:


7. World report on road traffic injury prevention, WHO, 2004

8. World report on road traffic injury prevention, WHO, 2004


DRUG USERS PERCEPTIONS OF DRUG DRIVING POST THE INTRODUCTION OF RANDOM ROADSIDE DRUG TESTING IN MELBOURNE, VICTORIA

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ABSTRACT

The perceived risks involved in drug use and drug driving is of increasing international interest and there are ongoing debates as to how to quell drug driving behaviour. In 2004 Victoria, Australia was the first policing jurisdiction to introduce Random Roadside Drug Testing (RRDT). Subsequently, RRDT has been implemented (or is under consideration) in most Australian policing jurisdictions. To date drug driving research has predominantly utilised epidemiological and experimental research methods. Existing epidemiological and experimental drug driving research has provided some insights into drug driving activity but is limited to producing quantitative data. Thus, experimental and epidemiological research cannot examine the broader issues surrounding drug driving. More recently a limited body of qualitative research into drug user’s perceptions and behaviours has emerged. However, there is only limited research into drug user’s perceptions of drug driving since the introduction of RRDT.

This paper presents the results of preliminary research into the perceptions of a sample group of drug users from Melbourne, Victoria. Forty participants (n=40), 25 males and 15 females, who were current drug users took part in semi-structured interviews and self report surveys. 32 (n=32) participants, 22 (n=22) males and 10 (n=10) females had engaged in drug driving activity. Cannabis, ecstasy and methamphetamines were the three most common drugs reported to have been used by participants immediately or several hours prior to or while driving. Furthermore, 37 (n=37) participants had been passengers in cars with drug drivers. Only two (n=2) female participants had not engaged in drug driving activity as either a driver or a passenger in a car of a drug driver. The majority of the participants had experienced drug driving activity and perceived such behaviour as relatively normalised in situations where drug use occurs. Participants agreed that the likelihood of detection by police prior to the introduction of RRDT was non-existent. All participants supported the idea of RRDT to encourage general road safety. Nevertheless, most participants believed that despite the implementation of RRDT the threat of detection remained low and many still engaged in drug driving behaviour.
The data collected in this research provides a valuable contribution to existing knowledge regarding drug use and driving through qualitative analysis of drug user’s perceptions and behaviours in relation to drug use and driving subsequent to the introduction of RRDT in Melbourne, Victoria. This data presented in this paper is intended to stimulate further discussion and to raise fresh questions in relation to drug driving behaviour. This research will also stimulate future drug driving research which may have implications for policy development. It also grants a voice to a sample group of drug users who are rarely heard in current debates surrounding drug driving.

1. INTRODUCTION

The perceived risks involved in impaired driving behaviour are a significant social, health and traffic safety issue. To date research examining impaired driving behaviour has focused on alcohol impairment and driver behaviour at the expense of drug driving research (Kelly, Darke & Ross 2004:319). However, in recent years the spotlight has shifted towards a focus on concerns surrounding drug driving and its potential social and public health consequences (Neale 2001:315; Kelly, Darke & Ross 2004:338; Armstrong, Wills & Watson 2005). Subsequently research has been conducted into drug driving, and interest in drug driving behaviour has generated debate as to how drug driving might best be addressed as a public problem.

Existing epidemiological research utilizing quantitative methodologies such as self-report surveys and written questionnaires have been conducted into the prevalence of drug driving activity mainly within drug using populations. Quantitative research conducted in Australia and abroad has found that it is very common amongst drug using groups to engage in drug driving activity or to be passengers in cars with other drug drivers (Albery et al 2000:197; Aitken et al et al 2000:45; Lenné et al 2001:307; Poyser et al 2002; Neale 2004:33; Davey et al 2005:65; Jones et al 2005:1; Degenhardt et al 2006:44; Duff & Rowland 2006:303; Furr-Holden 2006:85; Matthews et al 2009:29). In an Australia-wide study of the general public aged sixteen years and over, it was found that 16.9% of respondents had driven a car while under the influence of illicit drugs (Mallick et al 2007). However, according to the 2007 National Drug Strategy Household Survey (AIHW 2008) only 2.9% of survey respondents reported driving a motor vehicle while under the influence of illicit drugs. There remains limited and inconsistent data regarding the prevalence of drug driving within the general community (Kelly et al 2004:320; Davey et al 2005:44; Mallick et al 2007:9).

Furthermore, experimental research has provided an indication into how some drugs may impact upon driver behaviour (Kelly, Darke & Ross 2004; Mallick et al 2008). Nevertheless, the vast body of data generated by various experimental drug driving studies has proven inconclusive as to the exact role drugs play in affecting driver performance (Aitken, Kerger & Crofts 2000:40; Danton et al 2003:51). In contrast there is widespread consensus amongst researchers regarding the role that alcohol plays in significantly and adversely affecting driver performance (Kelly, Darke & Ross 2004; Ronen et al 2008; Matthews et al 2009). Scientific research into drunken driving has informed legislative changes and the development of law enforcement strategies to deter drunk driving (Starmer & Mascord 1994; Homel 1988;
Boorman 2007; Watson & Walsh 2008). As such there has been a gradual change in Australian cultural norms in relation to drink driving (Wilson 2009).

While existing epidemiological and experimental drug driving research has provided some insights into drug driving activity the research design of such studies has prohibited the examination of the broader contextual, social and cultural issues surrounding drug driving (Davey et al 2005:62). In an attempt to address this deficiency in knowledge there is a limited body of qualitative research which has been conducted into drug user’s perceptions and behaviours (see Lenton & Davidson 1999; Aitken et al et al 2000; Danton et al 2003; Davey et al 2005; Mc Intosh et al 2008). Qualitative research has been conducted in the United Kingdom and Australia into the perceptions of drug driving of clubbing recreational drug users (Neale 2001), “problem drug users” (Mc Intosh et al 2008), recreational and dependent drug users (Aitken et al et al 2000; Davey et al 2005). Existing qualitative studies have utilised semi-structured interviews and focus groups as part of the research methodology.

A key finding of existing qualitative research into drug driving is that the car plays a vital role in many drug users’ experiences, particularly in the case of dependent drug users (Davey et al 2005; Mc Intosh et al 2008). The car is viewed as a safe and private space in which to prepare and use drugs as well as providing transport to acquire drugs (Aitken et al et al 2000:42; Davey et al 2005:65; Mc Intosh et al 2008:249). Compelling data suggests that many drug users simultaneously engage in drug use and driving (Davey et al 2005:66; Neale 2001:318). Qualitative research has also found that drug users do not share uniform attitudes towards drug driving (Lenton & Davidson 1999:159; Aitken et al 2000:44; Neale 2001:321; Danton et al 2003:56; Davey et al 2005:67; Mc Intosh et al 2008:249). It has been found that drug users implement modification strategies when drug driving to minimise risks of detection and/or to minimise physical safety risks (Lenton and Davidson 1999:159; Neale 2001:322; Davey et al 2005:66; Mc Intosh et al 2008:250).

In regards to the perceived likelihood of detection from police, several international studies report that drug users believe that there is little chance of contact with police whilst engaging in drug driving activity (Lenton & Davidson 1999:159; Neale 2001:322; Danton et al 2003:56; Davey et al 2005:68; Mc Intosh et al 2008:252). A Scottish study revealed that only 12 out of a possible 61 recreational drug users involved in the research reported having been pulled over by police whilst drug driving (Neale 2001:322). These individuals reported that the police simply removed the drugs from their possession or that they had been prosecuted for drug possession (Neale 2001:322). Research conducted in Australia revealed similar findings in regards to perceptions of the likelihood of detection from police while engaging in drug driving. Davey et al (2005:68) found that drug users were largely unconcerned by the likelihood of detection from police as at the time of the research police could not test for drugs at the roadside. This finding is also supported by Stevenson et al (2001:513) who found that the perceived likelihood of detection from police was low among a sample group of Western Australian university students. 42% of the sample group believed that detection from police whilst drug driving is unlikely (Stevenson et al 2001:513).

Despite the absence of a clear scientific consensus regarding the risks of drug driving (Aitken, Kerger & Crofts 2000:40; Danton et al 2003:51), drug driving is now
considered a significant social problem (Armstrong, Wills & Watson 2005). Governance and policy responses have been to increase surveillance, control and punishment of drug drivers. In a world first, the Road Safety (Drug Driving) Act 2003 (Vic) s55D, s55E was enacted in the Australian State of Victoria to allow police the power to request that drivers undergo a random roadside drug swab test in a similar manner to random breath test (RBT) (Boorman 2007). Subsequently, RRDT is now used to detect and deter drug drivers in most Australian policing jurisdictions (Lenné 2007). Although referred to as ‘random’, RRDT is targeted in its approach (McDonald 2009). Police generally operate on main roads and entertainment precincts where heavy vehicle drivers, club and rave patrons and young people are driving. The targeting of these groups is most likely based upon the identification of certain groups of people as being more inclined to drug drive (Drugs and Crime Prevention Committee 2003).

In 2008 Victoria Police randomly tested 11,643 drivers and of that sample 138 drivers tested positive for illicit drugs (Anderson 2008:7). Road safety experts, policy makers and Victoria Police argue that the introduction of RRDT has been a positive step to reducing road trauma on Victorian roads and the statistics from the periods of 2004-2006 and 2008 demonstrate that the campaign has been effective (Boorman 2007:1; Boorman & Papafotiou 2007:217; Boorman & Owens 2007:17). However, it has been argued that RRDT has proven to have had no deterrent effect on drug drivers (McDonald 2009:39). It has also been suggested that there is an absence of unequivocal scientific evidence that RRDT has saved lives or reduced road trauma (Hall & Homel 2007:1918; McDonald 2009:39). Indeed, there remains a section of the community that continue to engage in drug driving activity despite the risk of detection from police in the form of RRDT (Lenné 2007:107).

Existing research provides a solid foundation on which to build a body of knowledge regarding drug user’s perceptions of drug driving. However, there is a need for further research to be conducted into drug driving activity (Kelly, Darke & Ross 2004:338). Furthermore, as RRDT has been implemented in Australian policing jurisdictions there is also a demand for qualitative Australian research which engages with the attitudes and perceptions of drug users. Drug users are frequently the target of road safety initiatives, but remain largely marginalized within policy debates. This preliminary research provides new knowledge with regards to drug user perceptions and behaviours in relation to drug use and driving and forms part of a larger qualitative research project on drug driving. This paper aims to provide the perspectives of a sample group of people, who are rarely included in current drug driving debates. By considering the voices of drug user’s researchers, police, policy makers and stakeholders can gain a greater understanding into drug driving behaviour. Indeed, by considering the perspectives of drug users will allow better informed policy making decisions.

2. METHOD

Forty (n=40) current drug users were recruited for this research. This specific sample number was selected upon the basis that it would produce a significant amount
of reliable data which would easily reach saturation point (Cresswell 1998). Saturation point is reached when the data begins to reproduce itself or enough data has been found (Cresswell 1998). Participants qualified for selection if they had used drugs in the past year. Recruitment was via snowball sampling of various networks. Snowball sampling is a form of non probability sampling (May 2001) which relies upon peer networks and referrals (Davey et al 2005). Participants were recruited from an initial group of primary participants (group A) via informal social networks and local drug agency networks. Potential participants from group A were approached with an information package and were able to keep the explanatory statement to peruse at their own leisure. This process encouraged potential group B participants to express interest in the project and to discuss their possible involvement.

Participants took part in semi-structured interviews and survey data collection. A short self report questionnaire was developed for the current study which allowed participants to complete self-report questions in relation to their drug use and driving habits. The questionnaire is an appropriate tool to encourage the triangulation process, the use of two or more different measures of the same variable. Triangulation is important in order to strengthen measurement, particularly when researching behaviour that is socially undesirable, stigmatised or illegal (Bachmann & Schutt 2007). The questionnaire and semi structured interviews were conducted between 26th May 2008-7th October 2009. Individual interviews and the administering of surveys were conducted at an agreed time in a group study room in a university library or at a local drug clinic. The research took a maximum of 1.5 hour per interviewee.

There are possible limitations involved in a research project of this kind that need to be acknowledged. A limitation is that the data collected from the sample group recruited via informal social networks and drug agency networks does not consider the experiences, opinions and values of people outside of the networks from which participants were selected (May 2001). However, the data presented does provide an interesting insight into the attitudes and perceptions of a sample group of drug users in Melbourne, Victoria. In order to protect participant’s identity participants real names have not been used. However, culturally appropriate pseudonyms have been assigned to the participants.
3. RESULTS

3.1 Demographic data

40 (n=40) participants took part in this research of which there were 15 (n=15) females and 25 (n=25) males. Participants were aged from 18 to 49 years. The average age of the male participants was 27.76 years and the average age of the female participants was 25.53 years. The participants typically held either an open drivers licence or were on their Learners or Probationary licence. Table 1 outlines the results of the self reported life time drug use. As demonstrated in Table 1 the three most commonly used drugs were cannabis, methamphetamines and ecstasy. Participants generally reported using drugs at social events, private parties, clubs, festivals and rave events. A minority of participants reported using drugs alone. Commonly participants reported using cannabis, ecstasy and/or methamphetamines every few weeks. However, it should be noted that certain participants reported much higher levels of cannabis, heroin and methamphetamine use. For the majority of participants drug use was associated with work, personal relaxation, social events, celebrations and general drug experimentation experiences. However, for some participants drug use was more harmful and as a result 10 (n=10) participants, four (n=4) females and six (n=6) males, were at the time of interview seeking assistance for their drug use.
Table 1: Self report lifetime use of drugs

<table>
<thead>
<tr>
<th>Drug Type</th>
<th>Total N=40</th>
<th>Males N=25</th>
<th>Females N=15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannabis</td>
<td>40</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Ecstasy</td>
<td>36</td>
<td>25</td>
<td>11</td>
</tr>
<tr>
<td>Methamphetamines</td>
<td>37</td>
<td>25</td>
<td>12</td>
</tr>
<tr>
<td>Cocaine</td>
<td>29</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>Hallucinogens</td>
<td>30</td>
<td>21</td>
<td>9</td>
</tr>
<tr>
<td>Ketamine</td>
<td>20</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Heroin</td>
<td>15</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Inhalants</td>
<td>14</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>GHB</td>
<td>7</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

3.2 Self reported drug driving activity as a driver or passenger

Overall 32 (n=32) participants (males n=22, females n=10) had engaged in drug driving behaviour as a driver. Table 2 demonstrates the results of the self report survey data pertaining to participants self report drug driving behaviour. The three most common drugs reported to have been used either immediately or several hours prior to or while driving were cannabis, ecstasy and methamphetamine. Of the participants who had drug driven, only seven had encountered drug buses. Five of the participants reported having undergone both the random breath test and the random drug test, while two participants had been requested to provide the random breath test but not a drug test. All of the participants who were drug tested passed the drug test. However, one participant reported that he was under the influence of a combination of methamphetamine and prescription medication at time. Furthermore, 37 (n=37) participants had been passengers in cars with drug drivers. Only two (n=2) female participants had not engaged in drug driving activity as either a driver or a passenger in a car of a drug driver.
Table 2: Self reported Drug driving activity as a driver

<table>
<thead>
<tr>
<th>Drug type</th>
<th>Total N= 32</th>
<th>Males N=22</th>
<th>Females N=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cannabis</td>
<td>28</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>Ecstasy</td>
<td>23</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Methamphetamine</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Cocaine</td>
<td>16</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Hallucinogens</td>
<td>10</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Ketamine</td>
<td>7</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Heroin</td>
<td>8</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Inhalants</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>GHB</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

3.3 Perceptions of Random Roadside Drug Testing

Participants overwhelmingly reported that prior to the introduction of RRDT the likelihood of detection by police when engaging in drug driving activity was nonexistent. Participants explained that in the period prior to the introduction of RRDT the only concern was in the likelihood of encountering a RBT. Many participants reported that in the period prior to the introduction of RRDT ‘designated drivers’ would often not consume alcohol but would engage in drug use.

However, most participants believed that since the introduction of RRDT the threat of detection was now existent but remained low, based upon anecdotal evidence. Interestingly all the participants acknowledged that the introduction of RRDT was a necessary measure to take in order to ensure general road safety. ‘Timothy’, aged 25 and an occasional social drug user, asserted: *I think that it [RRDT] is a good idea... I’m not really opposed to the drug driving [but] I think that you’ve got to do everything you can to keep people on the roads safe.*

Similarly, ‘Christian’, aged 31 and an occasional social drug user, agreed that RRDT is an important aspect of road safety. However, he explained that the associated anti drug driving education campaign must be improved. ‘Christian’ said:

*I actually support it given my experience. I think that random roadside drug testing does have a place beside roadside alcohol testing. I think there needs to be education around, like with alcohol with amounts and times, there is none of that*
with illicit drug taking and I understand that that is because we can’t be seen to condone it [drug use] but at the same time it [the campaign] looses its effectual edge because people are at some point going to or they are not [drug drive] and it doesn’t give them any information.

‘Shannon’, aged 26, who was a daily heroin user, also agreed that RRDT is an excellent road safety strategy. He stated: I think it’s a great thing that they’ve done. It would be better if they could bring something in that could detect heroin. Some participants also suggested that a 0.05 limit for cannabis use could be introduced. ‘Adam’, aged 24 and a daily cannabis smoker, suggested: Even if they make some kind of gauge. Like maybe 2 spliffs every hour and drive or… I mean you have some kind of line as to what is a limit. ‘Richie’, aged 42 and a frequent speed user, agreed that RRDT is important to promote road safety but was critical of the legislation which allows drug drivers to be penalised for having small amounts of drugs in their body. ‘Richie’ said: I think that it is a bit harsh you could only have a tiny little drugs in your system and you get charged.

Nevertheless, despite offering support for RRDT some participants expressed suspicion as to why the tests had not been brought in earlier given that Random Breath Testing for alcohol has been in place for many years. ‘Lisa’, aged 20, and an occasional drug user stated:

You have been breathalysed forever but they have only just started drug testing now, why has it only become an issue now? Are more people taking drugs? Or is it just because they have only just come up with the new technology?

Furthermore, some participants believed RRDT was implemented based upon moral opposition to drug use rather than unequivocal evidence that drug driving is dangerous. ‘Pearce’, aged 24 and a frequent cannabis user, commented:

I don’t believe that studies conclusively say that people under the influence of amphetamines are impaired in their driving…so I don’t think that it is based solidly enough on data…yes I think that it is moral. I think that it has probably been implemented because they figured that it was something that the broad population would see as being quite legitimate…I think they knew that they were going to get it [legislation] through and it was imposed just because those people who want to stamp out drug use and so this is just one of the ways of sending a message to society that drug use is unacceptable.

Of further interest is that despite supporting RRDT as a way to improve general road safety some participants engaged in forms of resistance to avoid encounters with drug busses. Some participants explained their personal strategies to avoid drug busses. Possible methods to avoid detection from police included: waiting a few minutes/hours after consuming drugs before driving; driving back streets to avoid drug busses on main roads; following a moving drug bus until it stops and then over taking it; rinsing your mouth with mentholated spirits or vinegar before being swab tested; not allowing the swab to touch your mouth; and pulling over and walking home.
It is evident the likelihood of detection by police prior to the introduction of RRDT was nonexistent. Many participants supported the idea of RRDT to encourage general road safety but most participants believed that despite the implementation of RRDT the threat of detection remained low. This finding is consistent with research which suggests that drug users believe that there is little chance of contact with police whilst engaging in drug driving activity (Lenton & Davidson 1999:159; Neale 2001:322; Danton et al 2003:56; Davey et al 2005:68; Mc Intosh et al 2008:252). Many participants were curious as to why RRDT had only recently been introduced. Some participants suggested that RRDT had been introduced for moral reasons rather than the unequivocal scientific evidence that drug use impairs driving performance. Furthermore, some participants reported implementing modification techniques to avoid detection from police. This finding reflects research suggesting that drug users implement strategies when drug driving to minimise risks of detection and/or to minimise physical safety risks (Lenton & Davidson 1999:159; Neale 2001:322; Davey et al 2005:66; Mc Intosh et al 2008:250).

4. DISCUSSION

This paper presents the results of preliminary research into the perceptions of a sample group of drug users from Melbourne, Victoria. The data collected in this preliminary research may not be representative of all drug users and drug drivers in general. However, the data collected in this research provides a valuable contribution to existing knowledge regarding drug use and driving. It provides an insight into drug user’s perceptions and behaviours in relation to drug use and driving post the introduction of RRDT in Melbourne, Victoria. The data presented in this paper has uncovered pertinent issues regarding drug user’s perceptions and behaviours, particularly in response to the introduction of RRDT. As previously acknowledged, the data presented in this paper can not be generalised. However, the data raises new questions to consider surrounding to drug driving behaviour and stimulates debate in regards to the effectiveness of RRDT on the perceptions and behaviours of drug users.

Among the sample group it was reported that engaging in drug driving behaviour as either a driver and/or a passenger is a relatively common experience. It can be suggested that drug driving behaviour is viewed as normalised behaviour for some drug users who engage in drug driving activity, as either a drug impaired driver and/or passenger in cars of drug drivers. Nevertheless, it is obvious that drug driving is not universally normalized by all drug users. An analysis of the data collected in this research suggests that the introduction of RRDT was perceived as broadly legitimate in terms of general road safety. However, the legitimacy of RRDT remains fragile and contested.

The data presented in this paper encourages consideration of the drug driving issue from the perspectives of drug users. It can be suggested that the anti drug driving campaign has not been completely effective and that the target audience remains to be convinced that there exists compelling scientific evidence proving that drug driving constitutes a significant risk. Furthermore, qualitative data presented in this paper suggests that some drug users view RRDT as a moral campaign against drug users. This paper argues that these factors may prevent RRDT being seen as completely legitimate by some drug users.
It can be suggested that in order for there to be a shift in cultural norms regarding drug driving, as evident with drink driving, the legitimacy of RRDT needs to be further established. It is interesting to consider the controversy and resistance surrounding RBT when first implemented in various policing jurisdictions to reduce the incidence of drink driving. Indeed, in Australia the introduction of RBT was greeted with public scepticism and resistance from sections of government (Senate Standing Committee on Social Welfare 1977:68; Homel 1988:110; Finnane 1994:101; Boorman 2007:2). However, RBT gained public support upon the basis of unequivocal scientific evidence proving that alcohol grossly affects driver performance coupled with successful education campaigns (Finnane 1994:103). This paper strongly argues that in order for there to be a shift in cultural norms regarding drug driving, as evident with drink driving, the legitimacy of RRDT needs to be further established.

Therefore, the data presented in this research has contributed new knowledge and insight into further understanding drug driving behaviour. This research encourages further debate and research into drug driving, particularly when legislative and law enforcement responses to drug driving are increasingly being implemented or considered in various policing jurisdictions (Adams, Smith & Hind 2008:6). Such research will positively inform legislation, policy development and law enforcement techniques.

5. REFERENCES


ABSTRACT

Road accidents involving heavy vehicles are known to have more severe consequences than other road accidents, and drink-driving is known to increase the accident risk considerably. However, little is known about drink-driving with heavy vehicles. A study was carried out in Norway to show the prevalence of alcohol among heavy-vehicle drivers in general and heavy-vehicle drivers involved in road accidents.

A literature review, as well as analyses of Norwegian accident statistics and in-depth reports of fatal accidents in Norway indicates that the prevalence of drink driving is far lower among drivers of heavy vehicles involved in crashes than among drivers of light vehicles. In Norway only about 1% of heavy vehicle drivers involved in injury or fatal crashes was found to have an illegal BAC level, while the proportion among drivers of light vehicles is about 6% in injury crashes and above 12% in fatal crashes. During the years 2005-2008 no driver of heavy vehicles involved in fatal crashes had an illegal BAC level. Among heavy-vehicle drivers in general road traffic, road-side checks conducted by the police led to the detection of one out of 2836 drivers of heavy vehicles who had an illegal BAC level (above 0.02).

Alcolock is a potential countermeasure against drink-driving. It can be assumed to eliminate a major part of drink driving in vehicles where it is installed. However, with the low prevalence of drink driving among heavy-vehicle drivers, it is highly unlikely that alcolocks in heavy vehicles might be a cost effective measure. It would have to prevent about 17% of all injury crashes with trucks involved, or about 12% of all injury crashes with busses involved in order to have greater benefits than costs from a societal point of view. Increased police control at checkpoints might reduce drink driving among heavy-vehicle drivers as well. It may be cost effective, if checkpoints are both unpredictable and impossible to avoid for truck or bus drivers.

1 This research project was financed by the Norwegian Public Roads Administration, Oslo, Norway
ALCOHOL PREVALENCE AMONG HEAVY-VEHICLE DRIVERS

Road accidents involving heavy vehicles are known to have more severe consequences than other road accidents (Björnstig et al. 2008), and drink-driving is known to increase the accident risk considerably (Assum & Glad 1990; Peck et al. 2008). However, little is known about drink-driving among heavy-vehicle drivers. Heavy vehicles are defined as trailers, busses, trucks and other vehicles weighing 7.5 metric tons or more. A study was carried out in Norway to show the prevalence of alcohol among heavy-vehicle drivers in general and heavy-vehicle drivers involved in road accidents. This study should also estimate the cost-benefit ratio of alcohol ignition interlocks or alcologs and of increased enforcement to reduce the prevalence of alcohol among heavy-vehicle drivers.

METHODS: SEVERAL SOURCES OF DATA

The results in this project are based upon data collected in this project, Norwegian accident data and data from the accident analysis groups of the Norwegian Public Roads Administration as well as existing Norwegian studies, international literature, and media references. Since the data collection methods vary between the diverse data sets, the methods are explained below for each data set.

Even if each kind of data has its limitations, they all indicate the same kind of results, a fact which strengthens the validity of the findings.

DRINK-DRIVING AMONG DRIVERS OF HEAVY VEHICLES

Surveys from the US (Lund et al. 1988), Canada (Lemire et al. 2002) and Europe (TISPOL, March 2009) have shown low prevalence of alcohol among drivers of heavy vehicles, less than 1 per cent of 317 truck drivers in the US, 0.29 per cent of 2,679 truck drivers in Canada and 0.19 per cent of a total 147,507 drivers of heavy vehicles in 21 countries in Europe. Participation was voluntary in the US and Canadian studies.

A roadside survey in Norway in 2005-06 showed no alcohol among 208 drivers of heavy vehicles (Gjerde et al. 2008). Participation in the survey was voluntary. In the Norwegian part (Utrykningspolitiet 2009) of a European roadside survey (TISPOL 2009) none of 1,098 drivers of heavy vehicles in Norway was reported for drink-driving.

Searching in Norwegian newspapers from 2002 to 2008, we found 25 cases, i.e. 3.6 per year, of drink-driving with busses and one case of an accident involving a driver of a heavy vehicle under the influence of alcohol.

The Mobile Police Force in cooperation with the TØI has carried out a road-side survey of alcohol among drivers of heavy vehicles from February through April 2009. A total of 2,836 drivers of heavy vehicles were stopped and breath-tested. Since the survey was carried out by the Police, participation was compulsory for the drivers stopped. Only one of these drivers had alcohol above the legal limit of 0.02 per cent (0.2 g/L blood alcohol concentration), i.e. 0.035 per cent of the tested drivers. The 95 per cent confidence interval is 0.005 – 0.250 per cent. In addition two drivers had alcohol in their breath, but below the legal limit.

Both existing Norwegian data, studies from abroad and the roadside survey carried out in this project indicate that the prevalence of alcohol among drivers of heavy vehicles is low and lower than among drivers of light vehicles.
DRivers of heavy vehicles involved in accidents

Norwegian accident data

Drink-driving increases accident risk in general. Present Norwegian road accident data contain hardly any information about the use of alcohol among the road users involved in accidents, but for the years 1983 – 1999 information about police suspicion of alcohol use was included (Statistics Norway 1983 – 1999). This information is likely to reflect the actual alcohol use of the drivers to a certain extent. The data for 1983 – 1999 show that drivers suspected of drink-driving had a higher risk of being involved in fatal accidents compared to injury accident, approximately 30 per cent higher among drivers of all heavy vehicles and 130 – 150 per cent higher among drivers of passenger cars.

All fatal accidents in Norway are studied in depth by the accident analysis groups of the National Public Roads Administration. For the years 2005 – 2008 we found 232 fatal accidents involving one or more heavy vehicles, and a total of 247 heavy vehicles were involved in these accidents. None of the drivers of the heavy vehicles were found to be under the influence of alcohol, giving a zero prevalence (95 per cent confidence interval of 0 – 1.21 per cent). One driver was impaired by amphetamine and one by cannabis. In principle all drivers involved in fatal accidents should be tested for alcohol, but in practice some drivers may not be.

In more than 50 per cent of these fatal accidents the heavy vehicle has not been active in causing the accident, whereas in less than 10 per cent of the accident it is obvious that no other road user has caused the accident. A lower share of the fatal accidents involving heavy vehicles is alcohol related than fatal accidents involving passenger cars.

Since the number of alcohol-impaired drivers in the fatal accidents is zero, and the prevalence of alcohol in the roadside survey was 1 of 2836 heavy-vehicle drivers tested, it is impossible to calculate the accident risk of alcohol impairment.

International studies

An analysis of 12 studies from the Australia (Attewell & Dowse 1992; Drummer et al 2003 and 2004), Canada (Lemire et al 2002) and the US (Lund et al 1988; FMCSA 2006; Crouch et al 1993; Blower & Campbell 1998; Office of Motor Carriers 1998; James & Nahl 1994; Williams et. al. 2003, NHTSA 1993) shows that the share of heavy-vehicle drivers impaired by alcohol is higher when the driver is guilty than when the driver is only involved – both for fatal and injury accidents. The share of alcohol-impaired drivers is higher in fatal accidents than in injury accidents. The share of drivers impaired by alcohol involved in fatal accidents is higher among drivers of trucks without trailers than among trailer drivers.

For bus drivers there are higher percentages of alcohol impairment among those involved in fatal accidents than among those involved in injury accidents. For all kinds of accidents and accident involvement the share of drivers impaired by alcohol is higher among drivers of passenger cars than among drivers of heavy vehicles and busses. This fact shows that alcohol impairment is of less importance for accident involvement for heavy-vehicle drivers than for passenger-car drivers, the reason being that alcohol impairment is less frequent among heavy-vehicle drivers than passenger-car drivers or that alcohol is less important for accident risk among heavy-vehicle drivers than among passenger-car drivers.
POSSIBLE REDUCTION OF DRINK-DRIVING AMONG HEAVY-VEHICLE DRIVERS BY ALCOHOL IGNITION INTERLOCKS

An alcohol ignition interlock or alcolock is a breathalyzer connected to the vehicle ignition. The engine can only be started after a breath test which shows no alcohol above a certain limit. Alcohol positive breath-test results are recorded in the interlock. Consequently, it is difficult to hide the result from the vehicle owner, who is often the employer. Alcolocks may have a bypass switch making it possible to start the engine even after an invalid test or a positive test. The point of the bypass switch is primarily to avoid delays caused by technical problems with the alcolock.

To reduce the possibilities of manipulating the alcolock there are several technical ways to disable other people than a driver already registered with the alcolock to make a valid breath test. The alcolock may be set to ask for repeated breath tests at irregular intervals during the driving to avoid drinking while driving or leaving the vehicle to drink with the engine running. For safety reasons such setting of the alcolock will not cause an immediate stop of the vehicle in case of a positive test, but the car will stop some minutes later.

Trials with alcolocks in commercial vehicles have been carried out in Germany, Norway, Spain and Sweden, giving diverse results as to percentage of alcohol positive tests (lockouts). These percentages were 0.192 and 0.337 in two Swedish studies (Bjerre 2005; Bjerre & Kostela 2008), 0.045 in Norway, 0.45 in Germany and 0.794 in Spain, i.e. no trial had a percentage above one (Silverans et.al. 2006). The high numbers of positive breath tests in Germany and Spain were explained by the fact that the drivers wanted to test the alcolocks. There is no information as to vehicles being driven by an alcohol-impaired driver. It was not possible to draw conclusions as to the number of trips made by impaired drivers being prevented by the alcolocks.

POSSIBLE REDUCTION OF DRINK-DRIVING WITH HEAVY VEHICLES BY INCREASED ENFORCEMENT

Enforcement by DUI checkpoints reduces the prevalence of drink-driving in road traffic and in road accidents, whereas enforcement by patrolling does not, but these results do not apply specifically to heavy vehicles (Elvik, Høyre, Vaa & Sørensen 2009. DUI checkpoints reduce the number of alcohol-related accidents by 17 per cent and all accidents regardless of alcohol by 10 – 15 per cent (Erke, Goldenbeld & Vaa 2009).

In Norway the following factors may influence the impact of enforcement on heavy vehicles:

- The risk of being detected is low for drivers of heavy vehicles because there may quite often be no space to stop heavy vehicles at the DUI checkpoints.
- The DUI checkpoints for heavy vehicles are predictable, because such checkpoints require enough space, thus being carried out at a few locations only.
- Heavy-vehicle drivers communicating with each other are able to warn each other if they see a DUI checkpoint.

Moreover, the possibility of license apprehension and suspension is likely to be more severe for heavy-vehicle drivers than for passenger-car drivers.

If the enforcement of drinking and driving rules directed towards drivers of heavy vehicles is to be effective, the checkpoints should be located in such a way that the possibility of detours is minimized.
INTERNAL ENFORCEMENT IN COMPANIES EMPLOYING DRIVERS

In 1994 an act was introduced in the US to the effect that companies employing drivers of commercial vehicles should carry out alcohol tests among 10 per cent of their drivers (FMCSA 2006). The legal limit for drivers of heavy vehicles is 0.4 g/l in the US. A study including fatality data from all states from 1988 through 2003 shows that the number of heavy-vehicle drivers impaired by alcohol and involved in fatal accidents has been reduced by 14.5 per cent due to this internal enforcement (Snowden et.al. 2007).

IMPLEMENTATION OF ALCOLOCKS AND DRINK-DRIVING ENFORCEMENT FOR HEAVY-VEHICLE DRIVERS

Alcolocks

Apart from voluntary alcohol checks before the drivers start driving, alcolocks are for the time being the only realistic alternative to police enforcement of drink-driving rules. Alcolocks prevent drink-driving, but the possible reduction in drink-driving caused by alcolocks depends on the alcohol prevalence before alcolocks are installed. If the alcohol prevalence among heavy-vehicle drivers is initially low both in road traffic and in accidents, the potential for reduction is also low.

A Norwegian initiative for the implementation of alcolocks in heavy vehicles by law or by voluntary arrangements will only include vehicles registered in Norway. Whether alcolocks will influence the competition between Norwegian and foreign vehicles, will depend upon the costs of alcolocks and the marketing value of a guarantee of drivers not being impaired by alcohol.

A possible implementation of alcolocks in heavy vehicles by law in Norway may be in conflict with the European Union rules concerning free flow of goods and services, and consequently implementation by incentives may be more realistic. Such incentives may be requirements of alcolocks installed in vehicles in tendering for transport contracts as has already been done in Sweden. The introduction of such requirements in tender contracts is likely to depend on the profitability or the accident reducing potential of alcolocks. Consequently, reliable information on the prevalence of alcohol among drivers involved in accidents becomes important.

If alcolocks come into use to a greater extent, rules regulating this use will be needed, and the authorities could help in developing such rules.

Police enforcement

Stopping heavy vehicles for checks of alcohol or other matters is more difficult because heavy vehicles require more space to slow down and to park. Consequently, it is a challenge for the police to find places to arrange check-points. The practical aspects of arranging heavy-vehicle checkpoints may vary between vehicle types, e.g. busses may have tight schedules and may be full of passengers.

Alternative enforcement

There is serious doubt whether it would be legally acceptable for the police to check heavy-vehicle drivers for alcohol before they start driving. Such enforcement can only be carried out voluntarily according to an agreement between the transport company and the drivers’ unions.
The National Public Roads Administration (NPRA) enforces technical vehicle standards. If the NPRA officers suspect that a driver has been drinking, they will inform the police. To increase alcohol checks the NPRA officers could check all heavy-vehicle drivers stopped. Such a practice would require an amendment to the Road Traffic Act.

COST-BENEFIT OF ALCOLOCKS AND ENFORCEMENT

Accident costs
The societal costs of traffic accidents in Norway are on the average about € 0.3 million per injury accident (Samstad, Killi & Hagman 2005). This is based on the average number of fatalities and injuries in accidents, and the societal costs of these. The societal costs of accidents involving heavy vehicles are about € 0.45 million per injury accident, which is due to the larger number of personal injuries in accidents involving heavy vehicles.

Alcolocks
A numerical example shows how many accidents must be prevented by alcolock if alcolock is to be socially cost efficient. The cost of purchasing and installing an alcolock is € 1888.9 and annual maintenance including mouth pieces is 1000 NOK € 111.1 (Haugen 2009). The discount rate is 4.5 per cent. The present value of the costs of an alcolock for 10 years is € 2768. The annual accident costs to be saved by an alcolock are then 3148 NOK € 350 per alcolock, equivalent to 0.0007 injury accidents per heavy vehicle (except busses). The actual annual number of injury accidents per heavy vehicle (except busses) is 0.004. If alcolocks will prevent 16.6 per cent of all injury accidents involving heavy vehicles (except busses), the benefit will equal the costs. For busses the annual accident costs to be saved by alcolocks equal 0.0009 injury accidents per bus. The actual annual number of injury accidents per bus is 0.008. If alcolocks may prevent 12.2 per cent of all injury accidents involving busses, the benefit will equal the costs.

According to Norwegian road accident statistics 0.8 per cent of all heavy-vehicle drivers involved in accidents, are impaired by alcohol. Even if this estimate is old and unreliable, it seems highly unlikely that alcolocks can prevent more than 16.6 per cent of injury accidents involving trucks and trailers or 12.2 per cent of all injury accidents involving busses.

For single companies or individual owners alcolocks may imply benefits and costs not included in the analysis of social costs above, e.g. marketing value. If a bus company has a driver who drives while alcohol-impaired, and this fact becomes public, the company may lose good will among passengers and authorities. It is, however, most difficult to estimate the value of such good will.

Increased enforcement
The present costs of enforcing the legal alcohol limit among heavy-vehicle drivers are not known. Depending on the reduction of accidents by increased enforcement, it is estimated that between € 0.5 million and € 2.9 million can be spent for increased drink-driving enforcement annually in the whole country in a socially profitable way.
DISCUSSION

Existing data for Norway, research in other countries and the data collected and analyzed in this project indicate that the prevalence of alcohol among heavy-vehicle drivers is extremely low both in general road traffic and in fatal accidents. Nevertheless, newspaper articles found on the internet show that drink-driving among drivers of heavy vehicles, including busses, exists in Norway.

The simple cost-benefit analyses of increased enforcement and the use of alcolocks indicate that the use of alcolocks to reduce drink-driving among drivers of heavy vehicles in Norway would not be profitable, but some more resources spent on drink-driving enforcement could be. However, what is an acceptable degree of a problem and the use of resources to reduce the problem further, can always be discussed.

POSSIBLE COUNTERMEASURES

At least three improvements in the data concerning drink-driving among drivers of heavy vehicles are necessary in order to allow the calculation of reliable risk estimates and cost-benefit analyses as well as evaluation studies of drink-driving countermeasures:

- Complete reporting of BAC among drivers involved in fatal accidents
- Reintroduction of information concerning suspicion of alcohol in the road accident statistics
- More and better road-side surveys concerning alcohol prevalence among heavy-vehicle drivers

Five possible countermeasures against drink-driving among heavy-vehicle drivers are likely to reduce drink-driving and to make the enforcement of drink-driving more effective:

- Coordination of enforcement of drink-driving and driving under the influence of other drugs
- More space for DUI checkpoints for heavy vehicles along highways
- Internal enforcement of drink-driving rules in transport companies
- “Alcohol gates” at ferry landings
- Breath testing for alcohol included in the enforcement of technical vehicle standards

Diverse ways to use alcolocks can also be considered, such as:

- Incentives for voluntary use of alcolocks, e.g. covering costs for alcolocks in school busses and public transport
- Transport authorities can start preparing rules to regulate the use of alcolocks
- Requirements for alcolocks in vehicles contracted for the National Public Roads Administration
- Co-operation with the road administrations and other authorities in other European countries concerning the use of alcolocks and the possible conflicts with European Union rules.
REFERENCES


Statistics Norway (2009) http://www.ssb.no/emner/10/12/20/vtuaar/


SAFETY ISSUES OF DROWSY/FATIGUE DRIVING AND COUNTERMEASURE MITIGATION

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ABSTRACT
Drowsy and fatigue driving is a major transportation safety concern and is responsible for thousands of accidents and numerous fatalities every year. The resulting harm of drowsy/fatigue driving could be even higher among commercial vehicles. Drowsy driving crashes are usually of high severity due to the drivers’ significant loss of control, often leading to unpredicted vehicle trajectory and no braking response. Reliable safety systems need to be devised to mitigate these conditions during driving. The most important challenge is to detect the driver’s condition sufficiently early, prior to the onset of sleep, to avoid collisions.

Various detection methods have been proposed by researchers and a few systems are available in the commercial market. In general, drowsiness detection methods fall into two major categories of monitoring physiological or facial conditions of the drivers and monitoring vehicle-related variables that are correlated to the driver’s level of drowsiness. Each method has its advantages and shortcomings. A reliable detection method needs to be integrated with a safety system including advisory warning, semi-control, or full control of vehicle, i.e., braking and/or steering to safe conditions. The nature and level of warning or control should also be carefully selected so as not to exacerbate a hazardous driving condition. The warning and control strategies need to be integrated with other in-vehicle safety systems (e.g. ACC, ESC, Lane Departure warning.)

This paper first reviews the statistical significance of the crash data due to drowsiness and fatigue conditions. Then, the issues concerning various detection methods are discussed. Finally, the strategies of driver warning or semi or full vehicle control for a drowsy driver mitigation system are reviewed. The concepts and approaches reviewed in this paper can be used for passenger or commercial vehicle safety system developers and researchers to design new or enhanced in-vehicle warning or control systems to minimize the severity of vehicle collisions or avoid collisions caused by driver fatigue and drowsiness.

1 INTRODUCTION AND PROBLEM SIGNIFICANCE

Drowsiness and fatigue are considered serious traffic safety problems causing numerous accidents (crashes) and fatalities each year. The traffic accident statistics in United States reflect a large number of crashes, about 80,000 crashes, due to drowsiness and a concerning number of fatalities as listed below.

The Fatal Analysis Reporting System (FARS 2008) contains annually updated census data for all fatal crashes occurring within the United States. The National Automotive Sampling System – General Estimates System (NASS-GES 2008) is a nationally representative sample of police reported crashes occurring within the United States. Each crash in the sample is assigned a weighting factor that can be used to provide an estimate of the frequency of such a crash occurring in the overall population for each given year. The data from both FARS and NASS-GES are derived from police accident reports.
Figure 1 shows the number of fatal crashes (vehicles) and fatalities (people) due to drowsiness and fatigue over a 10 year period from FARS (Fatal Accident Reporting System) data. Figure 2 and 3 show NASS/GES drowsiness related data including crashes, injuries, and fatalities for the period 1999-2008. Note that the number of fatalities is generally underestimated in the weighted NASS/GES data as compared to FARS data, which is the actual census.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Fatal Crashes</th>
<th>Number of Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>1352</td>
<td>1564</td>
</tr>
<tr>
<td>2000</td>
<td>1342</td>
<td>1538</td>
</tr>
<tr>
<td>2001</td>
<td>1214</td>
<td>1362</td>
</tr>
<tr>
<td>2002</td>
<td>1237</td>
<td>1418</td>
</tr>
<tr>
<td>2003</td>
<td>1083</td>
<td>1233</td>
</tr>
<tr>
<td>2004</td>
<td>1131</td>
<td>1298</td>
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<tr>
<td>2005</td>
<td>1017</td>
<td>1175</td>
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<tr>
<td>2006</td>
<td>978</td>
<td>1072</td>
</tr>
<tr>
<td>2007</td>
<td>908</td>
<td>1031</td>
</tr>
<tr>
<td>2008</td>
<td>719</td>
<td>827</td>
</tr>
<tr>
<td>Total</td>
<td>10981</td>
<td>12518</td>
</tr>
</tbody>
</table>

Figure 1. Number of fatal crashes and fatalities in crashes involving a vehicle in which a 'Sleepy, Fatigued or Drowsy Driver' was documented as a contributing factor over a 10-year period.

<table>
<thead>
<tr>
<th>Year</th>
<th>GES Weighted Estimates (PEOPLE)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Injury</td>
</tr>
<tr>
<td>1999</td>
<td>72161</td>
</tr>
<tr>
<td>2000</td>
<td>82526</td>
</tr>
<tr>
<td>2001</td>
<td>87753</td>
</tr>
<tr>
<td>2002</td>
<td>82333</td>
</tr>
<tr>
<td>2003</td>
<td>76309</td>
</tr>
<tr>
<td>2004</td>
<td>78738</td>
</tr>
<tr>
<td>2005</td>
<td>83664</td>
</tr>
<tr>
<td>2006</td>
<td>91822</td>
</tr>
<tr>
<td>2007</td>
<td>80571</td>
</tr>
<tr>
<td>2008</td>
<td>78670</td>
</tr>
<tr>
<td>Total</td>
<td>814547</td>
</tr>
</tbody>
</table>

Figure 2. NASS/GES data of occupants non-injured, non-fatally injured, and fatally injured in crashes due to drowsiness in 1999-2008 period. (Note: NASS/GES underestimates fatalities)
<table>
<thead>
<tr>
<th>Year</th>
<th>Number Of Vehicles</th>
<th>All Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>77602</td>
<td>96778</td>
</tr>
<tr>
<td>2000</td>
<td>90025</td>
<td>112983</td>
</tr>
<tr>
<td>2001</td>
<td>85282</td>
<td>107516</td>
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<tr>
<td>2002</td>
<td>83220</td>
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<td>80493</td>
<td>100213</td>
</tr>
<tr>
<td>2004</td>
<td>73443</td>
<td>95945</td>
</tr>
<tr>
<td>2005</td>
<td>83685</td>
<td>104712</td>
</tr>
<tr>
<td>2006</td>
<td>81023</td>
<td>106936</td>
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<tr>
<td>2007</td>
<td>81517</td>
<td>101672</td>
</tr>
<tr>
<td>2008</td>
<td>75760</td>
<td>96212</td>
</tr>
<tr>
<td></td>
<td>812049</td>
<td>1028054</td>
</tr>
</tbody>
</table>

Figure 3. Number of Vehicles whereby the driver of the vehicle was reported as 'Sleepy, or Fell Asleep' and Total Number of vehicles involved when at least one driver in the crash was reported as 'Sleepy, or Fell Asleep'

In general, 2008 highway safety data reflects a reduction in total number of injuries and fatalities, which could be partially attributed to the reduced travel and miles driven due to the country’s declining economic conditions. Thus looking at prior data (i.e., 2007 and before), over 1000 fatalities (from FARS), over 47,000 injuries (from NASS/GES) and 80,000 crashes annually are caused by drowsiness and fatigue, indicating an alarming safety problem. It is also believed that the statistical data underestimate the true magnitude of the problem because of difficulty and uncertainties in attributing the crashes to drowsiness and fatigue after the fact, during the accident data collection. The statistics definitely reflect the risk of drowsiness driving and justifies the need for development of countermeasures.

Countermeasures can be educational, cultural, and habitual in work and sleep habits, and legal in terms of regulating commercial vehicle operators, etc. These countermeasures require education, awareness and intervention at societal level, and are beyond the scope of our research. Here we focus on the issues and countermeasures, which are technology driven and can be implemented as in-vehicle or highway (infrastructure) systems to mitigate this safety problem.

First the characteristics of these types of crashes need to be understood. This includes the condition of the driver as well as the resulting consequences in vehicle control and vehicle trajectory. An effective active safety system, which can be used as a countermeasure for drowsy/fatigue driving need to include both an accurate robust detection method and an effective alerting method to provide feedback to the driver (e.g., alert warnings, haptics, etc.) or to intervene with the vehicle. The purpose of feedback or intervention is to avoid the collisions all together, if possible, or reduce the severity of the impending crash.

The following sections of this article cover the characteristics of drowsiness related crashes, various detection methods and their advantages and shortcomings, various interventions, and issues concerning integration with other safety systems and possible conflicting requirements.
2 CHARACTERISTICS OF DROWSINESS AND FATIGUE

There are several studies on driver drowsiness conditions. National Center on Sleep Disorders Research (NCSDR) of the National Heart, Lung, and Blood Institute of the National Institutes of Health, and the National Highway Traffic Safety Administration (NHTSA) held a special expert panel study on driver fatigue and sleepiness, entitled, “Drowsy Driving and Automobile Crashes.” (Strohl, K., et. al.) The following summarizes some of their important findings along with other references.

Drowsiness or sleepiness is a condition of the human body which requires the person to sleep. It is a function of sleep-wake cycle of the body, governed by the two homeostatic and circadian factors. Homeostasis relates to the neurobiological need to sleep after long periods of wakefulness, making it hard to resist sleeping (Dinges, 1995). “The circadian pacemaker is an internal body clock that completes a cycle approximately every 24 hours. Homeostatic factors govern circadian factors to regulate the timing of sleepiness and wakefulness.” (Strohl, et. al.).

Fatigue can be defined as the condition of the body related to “weariness or exhaustion from labor, exertion, or stress” (Webster Dictionary). Fatigue is associated with a temporary loss of power and it causes the inability to function properly or complete tasks. While drowsiness is a natural state of the body, fatigue is a condition or state, which is induced by external factors. One can argue that fatigue can cause sleepiness or vice versa. However, the commonality between the two is their effect on the human sensory processing, perception, and the various functioning abilities. They each may cause a loss of sensory receptions and motor actions of the human (driver.) Quantification and hence identification of fatigue may be more difficult than drowsiness because of the variety and complexity of the symptoms associated with fatigue. In general there are better and more subtle indicators on human body associated with drowsiness. Additional findings on the on the conditions and causes leading to causes of drowsiness for people with typical night sleeping cycles are:

- Sleepiness can occur due to disturbances to the circadian wake-sleep cycles.
- Two sleepiness peaks are observed during the afternoon and before the night sleep time (Richardson et al., 1982)
- Loss of one night sleep causes extreme short-term sleepiness.
- Habitual sleeplessness of one or two hours per night could cause chronic sleepiness during the day.
- Untreated sleep apnea syndrome (SAS) and narcolepsy could cause sleepiness.
- Sleepiness and performance impairment are neurobiological responses of the human brain to sleep deprivation and cannot be overcome by training, education, motivation, or other methods.
- Despite the intention or urge to stay awake, micro-sleeps may occur.
- Night workers, air crews, and travelers who cross several time zone, whose sleep is out of phase with the wake-sleep cycle, can experience sleep loss and sleep disruption that reduce alertness (Kerstedt, 1995; Samel et al., 1995).

The following are construed consequences of drowsiness on the human abilities and are hypothesized here based on Strohl et. al. workshop and drowsy driver experiments in driving simulators (Sayed, et al. 2001 and Mortazavi et. al. 2009):

- Drowsiness causes a delayed sensory processing ability and perception.
- Longer periods are needed to react to external stimulus during driving.
- Drivers response and ability to control the vehicle degrades substantially.
In summary under the drowsiness conditions the ability of the humans to operate and perform tasks degrades substantially. This causes a serious impairment during driving. Total impairment and loss of control occurs when drivers completely fall asleep at the wheel.

3 CHARACTERSITICS OF DROWSINESS RELATED CRASHES

As mentioned earlier, it is hard to determine exactly what percentage or what type of crashes occur due to drowsiness and fatigue. After crashes resulting in no harm, the drowsiness symptoms may vanish due to the hyperarousal and anxiety of the drivers involved in the crash. Those crashes which result in fatalities rely on the subsequent assumption and the deductions of the accident investigators and police reports. Only the portion of the data can be partially trusted that are from injury resulting crashes after which the drivers admit to drowsiness. The statistical data does not include this information, either. Despite these shortcomings in data, the available crash data and simulated experiments of drowsy drivers reveal certain common characteristics attributed to drowsiness crashes.

Horne and Reyner (1995) identified some of the vehicle and environment related criteria by which drowsiness related vehicle crashes could be identified; these include:

- Vehicle running off the road,
- No sign of braking,
- No mechanical defect,
- Good weather, and
- Elimination of speeding.

If additional information about the driver (from surviving crashes) is also available, it would help in this identification process. For example, researchers have found many factors that may influence driver fatigue/drowsiness including greater daytime sleepiness, less sleep, more difficult schedules, more hours of work, driver’s age, driver experience, cumulative sleep debt, presence of a sleep disorder, and time of day of the accident (Gander1999; McCartt et al., 2000). Sayed, et.al. reviewed the literature and listed findings of many researchers on this issue. Some of the important driver related factors are:

- Hours of continuous wakefulness before driving
- Loss of sleep; duration of last sleep period
  (Carskadon and Dement 1981); (Dinges 1995); (Naitoh 1992); (Carskadon 1993); (Stutts 2003); (Wilkinson et al. 1966); (Mitler et al. 1997); (Sweeney et al. 1995)
- Time of the Day, Night time
  (Dinges 1995), (Hertz 1988); (Jovanis 1991); (Miller 1978) and (Harris, 1972)
- Sleep disorder
  (sleep apnea or other related problems /quality of sleep/) (Stoohs et al. 1993); (Young et.al. 1997); (Stutts 2003).
- Consumption of drowsiness causing medications
- Monotony/length of driving
  (Akerstedt et al., 1994); (Shafer, 1993); (Desmond and Mathews 1996); (McCartt et al. 1996); (Fell 1994); (Sagberg 1999); (Thiffault and Bergeron 2003a)
- Driver personality and age
  (Zaidel 2000); (Artaud et al.1994); (Wyli et al. 1996); (Thiffault and Bergeron, 2003);(Campagne et al.2004)

Sayed, et. al. driving simulator experimentation showed that drivers who after a normal night of sleep had 17 to 18 hours of continuous wakefulness (a long day from 6 AM to 12
AM midnight) crashed within less than an hour of driving past midnight. Mortazavi et., al. had a somewhat similar findings on experiments conducted with commercial vehicle drivers in a truck driving simulator. After 18 hours of wakefulness, these subjects were asked to drive a monotonous roadway for over an hour in periods from 12 AM to 3AM. Almost all subjects in this experiment also revealed symptoms of fatigue and drowsiness and got into crashes. Other important statistics on crashes attributed to drowsiness from earlier NHTSA data are:

- The highest numbers of crashes occur during the period from midnight to early morning
- More than 40% occur between 1AM and 7AM.
- About 70% of crashes occur on rural highways with 55-65 mph speed limits. This generally provides a monotonous driving condition, prone to drowsiness.
- The first crash events are: 64% collisions with fixed objects (trees, guardrail, highway sign etc.), 17% collisions with another moving vehicle, 7% are rollovers, and 6% are collisions with parked vehicles.

The severity of the drowsiness and fatigue related crashes are typically high due to the significant loss of driver’s control. This loss of control may result in either delayed or no braking response, leading to run-off-road, rollover or a high speed collision (impact) with other vehicles or barriers.

4 DETECTION METHODS

Much of the information provided above (in section 3) on characteristics of drowsiness related crashes are suitable for the analysis and causation study of the drowsiness crashes. However, they cannot be directly used in the development of a robust detection system.

Drowsiness detection methods can be divided into two major categories: 1) Detection by measuring and observing the driver physiological symptoms and conditions and 2) Detection by measuring the vehicle variables and states, which are caused by the control actions of the driver. The latter, obviously is still dependent on the drivers’ condition and control action, but the methods in this category do not require any direct measurement or monitoring of the person, but rather focuses on measuring vehicle state variables during driving. Each method has advantages and shortcomings.

Each method first would require finding strong correlation between drowsiness/fatigue and one or more corresponding detectable/measurable variable, regardless of whether it is a human related or vehicle related variable. Fortunately, prior research shows such strong correlations do exist and can be measured, albeit not easily, and in some instances not practical for real-life driving. A second requirement is that the identified variable(s) (which correlate well with drowsiness) need to be measurable accurately and reliably. Then in order to have a detection method, a hypothesis should be developed which determines or defines the drowsiness condition. Then through experimentation of a large enough population (in simulator, track, or field operational tests) the variables’ thresholds or patterns based on the hypothesis need to be defined. Finally a detection method can be devised based on the measurements (via sensors), hypothesis, and threshold values, which when exceeded indicate a possible or anticipated drowsiness condition. The detection method when combined with a warning, alert, or vehicle control function, then can serve as a driver assistance safety system or countermeasure to drowsiness driving condition.
4.1 Detection by Measuring Physiological and Facial Symptoms

Detection by driver physiological/physical observation/measurements have been developed by using brain waves, heart rate/pulse rate, skin electric potential, eye closure, head nodding/posture, and facial expressions, gripping force on steering wheel among others.

**Eyelid closure** is one of the most obvious approaches to monitoring driver drowsiness. A number of different techniques are available for obtaining this measure. Erwin (1976) studied various measures to determine whether they were predictive of sleep and reported eyelid closure as the most reliable predictor of the onset of sleep. Haider and Rohmert (1976) evaluated blink rate, while subjects drove a truck simulator for four hours, and reported an increase in the blink rate between 80 to 100%. It seems quite obvious that if a driver eyes are closed, the ability to drive a vehicle will be greatly reduced.

Skipper et al. (1984) studied the performance of sleep deprived drivers, who performed a one and a half hour driving task. The experimenters used a linear potentiometer to manually track the eyelid movements of the drivers. They concluded that eyelid closures could be used as a measure for detecting drowsiness.

Ogawa and Shimotani (1997) analyzed data from a driving simulator experiment. They concluded that long duration blinks of half a second or more corresponds to subjective evaluation of sleepiness. The authors define a degree of alertness ($\alpha$) as $\alpha = \frac{\text{number of long duration blinks}}{\text{total number of blinks}}$. The driver was considered drowsy every time the value of $\alpha$ increased above a specified threshold value.

Different techniques have been used to track the eyelid closures. In the Dingus et al. and the Hardee et al. studies, experimenters manually track the eyelid movements. By looking at the video image on a monitor an experimenter used a linear potentiometer to track the position of the eyelids.

Ueno et al. (1994) used a method based on the Feret’s diameter of the eye to track the eyelid closures. The system analyzes the image of driver face taken by a video camera. After separating the eyes from the rest of the facial features, it defines a rectangular window around the eye on the basis of the Feret’s diameter of the eye. The maximum number of black pixels along the vertical axis of the window indicates the degree of eye openness and is used, as bases for judging whether eyes are open or closed.

Among all eye-measurements metrics, PERCLOS is now the most widely accepted metric (Knipling, R. and Rau, P.). A PERCLOS drowsiness metric was established in a 1994 driving simulator study as the proportion of time in a minute that the eyes are at least 80 percent closed. (Wierwille et al., 1994) Based on research by Wierwille and colleagues (1994), FWHA and NHTSA consider PERCLOS to be among the most promising known real-time measures of alertness for in-vehicle drowsiness-detection systems.

**Facial expressions** have also shown strong correlation with driver fatigue, drowsiness and vigilance. Oiang Ji et.al. (2001) developed methods for real time visual cues extraction for monitoring driver’s vigilance. From the same research group, Tong, e. al. developed methods for eye position detection and tracking with facial movements.

Wierwille and Ellsworth (1994) found that trained observers could rate the drowsiness level of drivers based on video images of driver faces.

**Electrooculography (EOG)** is a technique, which involves the measuring of eye movements through electrodes attached to the skin surrounding the eye. The detection of the eye movements is good only when the movements are visually unambiguously definable and isolated. Failure rate is very high for atypical eye movements.

Ogawa and Shimotani (1997) used the angle of inclination of eye corners to track the eyelid closures. This angle is steep when eyes are open and shallow when eyes are closed.
Seki et al. (1997) developed a method, which uses reflection from the retina (bright pupil) to determine whether the eyes are open or closed. In this method a charge-coupled device (CCD) camera, using infrared light to illuminate driver face, captures the driver facial image. The facial image signal is converted into digital images. The pupils are identified on the basis of their geometric features and relative positions using the binary image. The eyes are considered closed when there is no reflection from the retina.

The Electroencephalogram (EEG) recorded from the human scalp is the most important physiological indicator of the central nervous system activation and alertness. Many researchers have used this physiological indicator to identify the period of drowsiness. From a state of fully awake to a state of fully asleep, the EEG varies in frequency bands ranging from 0 to 20 hertz. These frequency bands are classified as follows in Table 4:

<table>
<thead>
<tr>
<th>EEG Wave Type</th>
<th>Frequency Range (Hz)</th>
<th>Frequency Rate</th>
<th>Alert or Drowsiness State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta waves</td>
<td>0 – 4</td>
<td>Very Slow</td>
<td>-</td>
</tr>
<tr>
<td>Theta waves</td>
<td>4 – 8</td>
<td>Slow</td>
<td>Sleep State</td>
</tr>
<tr>
<td>Alpha waves</td>
<td>8 – 12</td>
<td>Mid-range</td>
<td>Relaxed Experience/Unfocused Attention</td>
</tr>
<tr>
<td>Beta waves</td>
<td>13 – 20</td>
<td>Fast</td>
<td>Alert State</td>
</tr>
</tbody>
</table>

An alert mental state is accompanied by fast frequency beta activity, whereas a sleep state is accompanied by slower theta activity. Alpha activity is associated with relaxed experience during which attention is unfocused, showing drowsiness.

Various methods are available to extract features from a segment of the raw EEG. In time domain, average value, standard deviation, and sum of squares of EEG amplitude are most commonly used. In frequency domain, energy content of each band (β, α, θ, δ), mean frequency, and center of gravity of the EEG spectrum are commonly used. Other models such as Auto Regressive Moving Average (ARMA) and power spectrum estimation are also used to extract EEG features.

Torsavall and Akerstedt (1987) measured continuous EEG spectra for eleven train drivers. They reported that lapses of attention were preceded by increase in low frequency EEG activity. The researchers also showed that the driver vigilance tends to diminish rapidly after prolonged driving and can be measured by means of spectral analysis of the EEG.

Richardson et al. in the European PROMETHEUS project used EEG in conjunction with other variables to find correlation between drowsiness and EEG. Alkerstedt and Gilberg (1990) and Huang et al. (1996) used fluctuations in mean frequency of EEG to detect the state of alertness. Generally, EEG is considered suitable for making accurate and quantitative judgments of alertness levels.

Although physiological and eye monitoring methods can provide good accuracy for detection of drowsiness, there are some major issues in their utilization. Most physiological detection methods require attachment of electrodes (e.g. EEG) or sensors to driver body and hence render them intrusive and impractical for real life applications. Although substantial advances have been made in camera and vision processing systems, there still remain some inaccuracies and reliability issues with facial and eye-monitoring methods in dealing with changes in light conditions, correction glasses, and angle of face. Other conditions can also seriously affect the performance of image processing systems.
4.2 Detection by Measuring Vehicle State Variables

Detection of drowsiness by measurement of anomalies in driver control actions resulting in changes in vehicle states (steering/lane keeping, accelerating, etc.) have also been tried by various researchers. These methods have the advantage of being non-intrusive to the drivers. In this category, the focus of measurement is not on the condition of driver but is on the output of the vehicle as controlled by the driver. The vehicle control systems that might be monitored for sensing driving operation include the steering wheel, accelerator, and brake pedal. The vehicle variables that can be measured include vehicle speed, acceleration, yaw rate, steering angle, and lateral displacement.

Wierwille et al. (1992) discussed the performance measures as indicator of driver drowsiness in detail. A summary of these measures is presented in the following sections.

Vehicle steering has been cited by many studies as the characterizing driving, which could be correlated with EEG parameters that can predict the driver drowsiness. Hulbert (1972) found that the sleep-deprived drivers have a lower frequency of steering reversals (every time steering angle crosses zero degree) than that of rested drivers. Mast et al. (1996) and Dureman and Boden (1972) have found that there is a deterioration of steering performance with drowsiness.

According to Kahneman (1973), effort and SWRR (Steering Wheel Reversing Rate) are linked. He showed that the SWRR decreases under the influence of substances such as alcohol, which reduces driver activation level. Ryder et al. (1981) found that the frequency of steering reversals decreases with time on task.

Yabuta et al. (1985) hypothesized that when a driver is drowsy or falling asleep his/her steering behavior becomes more erratic, i.e. “more frequent steering maneuvers during wakeful periods, and no steering correction for a prolonged period of time followed by a jerky motion during drowsy periods.”

Dingus et al. (1985) found that several steering related measures, such as steering velocity, steering wheel increment, and low velocity steering, can be used to predict drowsiness. Mackie and Wylie (1991) provided a review of patterns of steering wheel movements and vehicle speed. They have affirmed the complexity of the analysis of these two variables and reported that the environmental factors could highly affect the steering precision.

A study conducted by Chaput et al. (1990) suggests that there exists some correlation between micro steering movements and drop in vigilance. During high vigilance (alert) periods small amplitude steering wheel movements are frequent, but during fatigued periods large amplitude movements are more visible.

Elling and Sherman (1994) analyzed actual driving data from one-hour of continuous driving by professional drivers. They reported that steering wheel reversals and standard deviation of steering wheel angle are two measures that show some potential as drowsiness indicators. They also reported that gap-size (i.e. the angle that the steering wheel must be reversed before being counted as a reversal) has a major influence on the reversal rate. Their gap-size function has a dead-band that disregards any extremely small reversals such as those due to road variations.

Fukuda et al. (1995) developed a driver drowsiness detection system at the Toyota Motor Company. The authors used steering adjustment time to estimate drowsiness. Their method consists of the following steps: i) Steering adjustment intervals are calculated at different speeds for alert conditions (learning). These intervals vary with speed and individual behavior but it follows the same pattern. ii) The steering adjustment intervals are normalized at 80 km/hr speed. These intervals are constantly calculated. Whenever it reaches a threshold value, the driver is classified as drowsy. The value of drowsiness threshold is not constant but it varies with speed. The driving threshold is calculated by taking the product of
the mean value of learned steering adjustment intervals in the normal state and the mean value of most recent steering adjustment intervals. The results show good correlation with EEG.

Siegmund et al. (1996) conducted an experiment based on the performance of 17 long haul truck drivers under alert and fatigued conditions on a closed circuit track. They presented a steering based set of weighing functions. These functions are based on steering angle and steering velocity. According to the researchers these weighing functions are correlated with EEGs and subjective evaluations of drivers. According to their findings, phase plots of steering wheel angle verses steering wheel velocity can be used as an indicator of drowsiness.

Based on the prior findings Sayed and Eskandarian (2001) developed an unobtrusive method of detecting drowsy drivers by monitoring the steering activity of drivers using a trainable artificial neural network. The result of their tests in a vehicle driving simulator demonstrated over 85% success rate in detection accuracy and less than 14% false alarms. Later Eskandarian and Mortazavi (2007) proved the method was equally successful in testing commercially licensed drivers in a truck driving simulator (at the Center for Intelligent Systems Research of The George Washington University). These were experiments conducted on drowsy drivers after 18 to 20 hours of wakefulness during a long day. The shortcoming of this method is the need for a large set of exemplars for training the neural networks which requires samples (steering time histories) of both alert and drowsy driving. Complete experimental results are provided in Mortazavi and Eskandarian (2009).

Eskandarian and Mortazavi (2008) provisionally patented a new method of detection based on a signal processing scheme on steering signal. This method requires only samples of alert/normal driving but no samples of drowsy driving. After an initial training phase, it utilizes a signal processing and pattern recognition technique to identify drowsy drivers. The new method showed a similar success rate in detection as the earlier ANN method.

Vehicle Speed variability in general has not shown any significant results that can be used to predict drowsiness. Safford and Rockwell (1967) reported no increase in speed variability during a 24-hour driving experiment. Riemersama et al. (1977) recorded vehicle speed during an 8-hour night driving experiment. They reported an increase in the standard deviation of speed, calculated over 45 minute intervals, after the first 3 hours of driving. Mackie and O’Hanlon (1977) recorded speed in a 6 hour driving experiment, with a 45 minute pause after three hours of driving. The researchers reported a regular increase in the standard deviation of speed from the third driving hour.

Maintaining Vehicle Lateral Position (lane tracking ability) decreases as the time on task increases (Mast et al. 1996). Skipper et al. (1984) found that measures related to vehicle lane position could be used to detect drowsiness. Variables such as the number of lane deviations, the standard deviation of lane position, and the maximum lane deviation are found to be highly correlated with eye closures. According to Dingus et al. (1985), the mean square of lane deviation and mean square of high pass lateral position show good potential as drowsiness indicators.

Stein (1995) studied the effect of impairment on driving performance in truck drivers. Using data from a simulator experiment, Stein found that the standard deviation of lane position increases remarkably after the driver gets fatigued at 13 hours of driving. The standard deviation of the heading error also began to increase after 13 hours.

Pilutti and Ulsoy (1995) performed experiments on the Ford driving simulator at the Ford Research Laboratory for detecting driver fatigue. The results, reported by the authors, show that only the standard deviation of lateral position show significant change and correspond well with PERCLOS model.
**Yaw/Brake/Acceleration** activity or variances may have some relationship with drowsiness but are not proven to be solid indicators. Dingus et al. (1985) found that the yaw deviation variance and the mean yaw deviation (calculated over a three minute period) show some promise to be considered as drowsiness indicators. However, several researchers have found no relation between drowsiness and vehicle yaw, brake, or acceleration. Safford and Rockwell (1967) analyzed data from a twenty-four hour driving experiment and reported that the accelerator pedal reversals are correlated with driving time. But according to the literature review conducted by Dingus et al. (1985), there is little evidence of any relation between accelerator activity and time or drowsiness. In addition, researchers such as Brown (1966) found no evidence of any correlation between accelerator and drowsiness.

**Suitability of Vehicle State Measurement for Drowsiness Detection** or the main advantages and disadvantages are:

- No electrodes and wires are to be attached to the body of the driver.
- No cameras, monitors, light sources or other devices are to be aimed at the driver.
- No dependence on the environmental and other road conditions.
- Less computational power is required for processing signals such as steering angle, which makes the online processing of data easily achievable.
- Hardware requirement for capturing signal from vehicle components such as steering, throttle, and gas paddle are much less than that required for an image processing or human body signals. These are often much cheaper and readily available.
- These methods are better suited for implementation due their non-obtrusive nature.
- Due to variation in the dynamics of different types of vehicles, a universal system that will fit all vehicles is very difficult to achieve. These systems must be tuned in for the type of vehicle in use.
- Accuracy may not be high as compared to EEG monitors, since EEGs are constantly attached to the body and deliver a continuous signal (even when car is not in motion.)

5 **COUNTERMESURES/WARNING AND INTERVENTION FEEDBACK**

A successful real-life implementation would mandate several other product requirements, typical of automotive safety systems. Factors like the ability to sense the required variables with inexpensive and available sensor technology, system robustness, minimization of false alarms, driver options in level of intervention and adaptability, comfort level and overall feasibility and consumer acceptance of the system are among many demanding requirements.

5.1 Methods and Approaches for Countermeasures

There are various methods of safety countermeasures for drowsy driving. Preventive methods focus on behavioral changes through education and altering the driving culture. These are behavioral and educational methods, which attempt to change the driving habits and life-style related risks through education, change of work hours, change of sleeping cycles, and all other measures that deal with the root cause of the problem. They intend to prevent or minimize driving while under drowsiness conditions.

Alternatively, another category of countermeasure is to intervene during driving when a condition of drowsiness is detected. The main issues of these methods are when, how, and at what level to interact with the driver. The emphasis is to ensure that any intervention method should result in a safer driving condition, minimize risk of crashes, and be acceptable by the drivers. This requires that the interventions or feedbacks be robust, accurate, and minimize nuisance feedbacks to the driver.
5.2 Modes and Levels of Feedback to Driver

Vehicle related countermeasures for any driving hazard will have some level of intervention with either the driver or the vehicle. The active safety systems or countermeasures for drowsinessness can be categorized according to their level of interaction with the driver or their intervention on the driving controls. Automatic systems such as anti-lock brake sys (ABS) or electronic stability control (ESC) function without driver’s intervention (beyond the normal vehicle control inputs). Other systems provide information or warning to the drivers, and hence act as a driver assistance system. Driver assistance systems could have intervention with driver as pure information, warning/alert signals, partial control or, automatic control. Each level provides different type of interaction and intervention with the driver and vehicle.

Table 2 lists these intervention levels.

At one extreme is the automatic control functions, which are vehicle dynamics related controls that could be transparent to the driver. At the other extreme are the pure informational systems, which simply provide useful information to the driver and enhance the situational awareness. Examples are weather advisories and information about icy road surface conditions, etc. In between these extremes are safety and comfort systems with various levels of intervention. These systems could warn the driver, inform of a corrective action, or take partial (haptic) control (e.g. assisted braking). For example, the Lane Departure Warning system, recently offered by several manufacturers, warns the driver of a lane departing vehicle by use of a camera which monitors vehicles lane tracking. Many of the driver assistance systems are in the form of information and warning signals to the driver and can be disengaged optionally.

For drowsy drivers, the type of level of intervention needs to still be studied in further details because of the complexity of the consequences of the alerting signals. The driver’s immediate reaction is a function of severity of his/her state of drowsiness. A driver on the onset of sleeping may be safely warned to bring the vehicle to stop, while a completely dosed off driver may react undesirably to the wake signal. Safe automatic braking and bringing the vehicle to a safe parking may be best option for commercial or hazmat vehicles, should the legal issues of overtaking of a vehicle’s control be worked out.

Table 2. Categories of Active Safety System According to Levels of Feedback to Driver

<table>
<thead>
<tr>
<th>Categorization Level of Active Safety Systems</th>
<th>Function or Task (Sensing, Estimating, Computing)</th>
<th>Interaction with Driver or Intervention in Driving Task (Action)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informational</td>
<td>Sense environment, road, weather, Retrieve real-time or archival data</td>
<td>Enhances situational awareness and condition monitoring: Display and Present the Relevant Information</td>
</tr>
<tr>
<td>Warning</td>
<td>Sense condition, Evaluate situations &amp; potential hazards, Decide when and what to do, Decide corrective action</td>
<td>Alerts the driver of potential hazards &amp; possibly recommend corrective actions (wake up, slow down, brake, steer)</td>
</tr>
<tr>
<td>Partial (Semi) Control</td>
<td>Sense condition, Evaluate situations &amp; potential hazards, Decide when and what to do, Decide corrective action</td>
<td>Provide both warnings/alerts and Partial control functions (e.g. apply partial brake, stiffen gas pedal to retard speeding)</td>
</tr>
<tr>
<td>Automatic (Full) Control</td>
<td>Sense condition, Evaluate situations &amp; potential hazards, Decide when and what to do, Decide corrective action</td>
<td>Apply the vehicle control function as needed (automatically apply the brakes, ESP, etc.)</td>
</tr>
</tbody>
</table>
5.1 Integration with Other Safety Systems

Various active safety systems are emerging in automobile and truck market. A major requirement of drowsiness detection/safety countermeasures is the ability to function effectively in conjunction with other on-board systems. In fact this must be a paramount feature of this particular safety system. Lane departure warning is a camera based system monitoring lane keeping ability of the driver/vehicle. A lane departure control implements left and right braking and traction to subtly guide the vehicle in the lane. A driver’s severe reaction as a consequence of drowsiness, however, may not be treated appropriately with this system. The key element is to detect drowsiness patterns sufficiently early and to provide warning alerts or interventions earlier, before the deeper sleepy or dose off conditions occur. Results from Sayed and Eskandarian (2001) show that their ANN based detection method could predict state of drowsiness on drivers, up to three minutes before crashes occurred (i.e. total lane departure or run off road). This is promising because it provides significant time for reaction and warning.

A drowsy driver warning or automatic control system could potentially work in unison with a lane departure control (tracking control), and ACC to assist the driver to avoid crashes.

6 CONCLUSIONS

Drowsiness and fatigue pose serious problems for driving safety. Annual crashes, serious injuries and fatalities are at a high level, necessitating development of effective countermeasures. Although it is not easy and definitive to attribute crashes to drowsiness, there are methods which can extract sufficient information to identify crashes, which have been caused by fatigue and drowsiness in post crash accident data collection and analysis. The basic understanding of human drowsiness and fatigue conditions reveal that there are strong correlations between these human states (i.e. fatigue and drowsiness) and detectable physiological measures such as EEG, facial expression, eye-closure, etc. The reviews provided in this article demonstrate a variety of findings in this area, which all support the possibility of driver’s state detection. Furthermore, research has also shown that driver steering and lane keeping correlates with the level of drowsiness, i.e. these variables reflect sufficient changes and anomaly during drowsy driving periods as compared with normal driving. This difference in driver’s ability to steer the vehicle has become the cornerstone of different unobtrusive detection methods for drowsiness. Monitoring the vehicle variables (i.e. lane keeping or steering function) is certainly simpler and more practical than the physiological monitoring of the driver. Research by the author and other researchers show the promise of the unobtrusive detection methods. General guidelines and requirements of drowsy driving countermeasure developments have been outlined in this paper, too. The critical issue in alerting or assisting the drowsy driver is to be effective in regaining control of the vehicle without the potential harm of undesirable driver reaction. The warning or haptic driver assistance should work as integral part of other existing lane departure control and longitudinal control systems. Some safety systems in luxury vehicle are appearing in the market, which seem to have been built on this premise. Future work in this area concerns the evaluation of true effectiveness of these systems in real-life driving and enhancement of countermeasures as required.
ACKNOWLEDGEMENTS
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REFERENCES


Huang, R. S., Kuo, C. J., Tsai, L. L., and Chen, O. "EEG Pattern Recognition - Arousal States Detection and Classification." IEEE International Conference on Neural Networks, Washington, DC.


Contents session 8  Modelling II

A Computational Model to Assess the Impact of a Set of Policy Measures on Road Safety at the Regional Level
*Geert Wets, IMOB – Hasselt University, Belgium*

An Approach for a more Precise Road Scoring
*Ahmet Yildiz, Dep. For Spatial Development, Infrastructure and Environment Planning, Vienna, Austria*

Computer Aided Road Safety Inspections
*Ahmet Yildiz, Dep. For Spatial Development, Infrastructure and Environment Planning, Vienna, Austria*

Development of a New Driver Behaviour Model through a Novel Object Detection Technique
*Dr Majid Sarvi, Civil Engineering, Monash University, Australia*

Automated Road Safety Analysis Using Computer Vision Techniques
*Tarek Sayed, University of British Columbia, Canada*

Macroscopic Safety Investigation at the Traffic Analysis Zone Level
*Mohamed Abdel-Aty, Department of Civil, Environmental and Construction Engineering University of Central Florida, USA*
A COMPUTATIONAL MODEL TO ASSESS THE IMPACT OF A SET OF POLICY MEASURES ON ROAD SAFETY AT THE REGIONAL LEVEL

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ABSTRACT
Policy measures in road safety are frequently taken at a locational level (e.g. at a particular risky intersection). This approach does not facilitate assessing the effects of policy measures in a broader perspective. To achieve this, a method estimating road safety effects at a regional level is a valuable tool. Moreover, several policy measures are often implemented simultaneously in the real world. To model the effect of a set of measures on road safety, methods for estimating the combined effect of policy measures are required. In most cases, the accident modification factors are multiplied. The term “modification factor” refers to the accidents that remain after a measure has taken place. In that case, a measure effect is assumed to be independent of the effects of any other measure and to remain unchanged when introducing other measures. However, this assumption is likely to be incorrect in a lot of cases. One would expect dependence among measure effects applied around the same time. Therefore, the dominant common residuals method will be illustrated in this paper. The basic idea underlying this method is that the most effective measure in a set dominates the others to some extent, by partly or fully influencing the same group of accidents or the same risk factors.

A model assisting regions to assess the road safety effects of a set of measures on a broader area and aiding in selecting measures resulting in the most efficient cost-benefit ratios is discussed. The regional road safety explorer (RRSE) model developed by SWOV (Reurings and Wijnen, 2008) is used as a starting point for the region of Flanders in Belgium. The model consists of five stages: the reference situation, the baseline prognosis, the measure prognosis, the number of saved injury accidents and the cost-benefit analysis. The reference situation describes the current traffic performance (exposure) and the current road safety situation in the region. The model considers a long time perspective and therefore, the main future evolutions in exposure and autonomous risk are taken into account in the baseline prognosis. The measure prognosis relates to the situation after applying and estimating the effectiveness of measures on road safety. The main outputs of the model are the number of saved injury accidents (and/or casualties) and the cost-benefit ratios of the measures taken. By expressing the saved injury accidents in monetary values, the cost-benefit analysis determines whether the applied measures are cost-effective. Through this analysis, policy makers are assisted in selecting policies that make the most efficient use of resources.

1 INTRODUCTION
Road safety is an important issue that can be tackled by means of measures. In practice, different road safety measures are often taken simultaneously, causing potential dependences between them. It is thus useful to consider the dependence of measure effects in a
computational model for road safety. So far, the most common way of dealing with more than one measure is to multiply the accident modification factors to estimate the combined effect of road safety measures. This method has been proposed by Smeed (1949). This method assumes that the effectiveness of one road safety measure is independent of the effectiveness of any other measure and remains unchanged when other road safety measures are introduced. In reality, effects will not be entirely independent. Measures are likely to influence some of the risk factors that are the targets of other measures, thus reducing their likely effects (Elvik, 2008; Elvik, 2009). For instance, pedestrian reflective devices will be less effective on well lit roads than on unlit roads; seat belt ignition interlocks will render any other measure designed to increase seat belt wearing less effective (Elvik, 2009). Further, Nilsson (2004) has shown that those who drink and drive are more likely than those who do not, to also speed and not wear seatbelts. If seatbelt ignition interlocks were mandatory, the risk associated with drinking and driving would possibly be reduced as well, and any measure designed to curb it would be less effective. In a study assessing the combined effects of road safety measures, Elvik (2009) demonstrates that the effect of each of six road safety measures (concerning alcohol sales, unemployment, speed cameras, publicity campaigns, drink-driving enforcement and black spot treatment) are considerably weakened when they are combined. Such dependences are not taken into account by most current models, and only the individual effects of the measures are considered. The hypothesis is that measures affect road safety independently. To address this research gap, dependence between measure effects will be taken into account in the model presented here. It should be noted that some measure effects reinforce each other. For example, Vaa et al. (2009) found that a combination of road safety campaigns and increased enforcement with respect to seatbelt usage is associated with more reduced accident counts. However, cases of reinforcing measures are outside the scope of the current paper.

The objective of this paper is to present a computational model assessing the impact of a set of policy measures on road safety at the regional level. The combined effect of road safety measures introduced at the same time is evaluated using the dominant common residuals method.

The remaining of this paper is structured as follows: in Section 2 the essential theoretical concepts of the model are discussed. Next, the effect of measures is assessed taking dependence between measure effects into account. Road safety data on highways in Flanders are used. The outcomes in terms of the number of injury accidents saved and cost-benefit ratios are discussed (Section 3). Finally, uncertainty analysis is performed to examine the robustness of the model output (Section 4) and this paper ends with the discussion, conclusions and topics for future research in Section 5.

2 THEORETICAL CONCEPTS OF THE MODEL

This section describes the structure of the model. The model consists of five stages: the reference situation, the baseline prognosis, the measure prognosis, the number of saved injury accidents and the cost-benefit analysis. The results are computed based on the formulae presented in Reurings and Wijnen (2008). Section 2.1 elaborates on the reference year. Section 2.2 discusses the baseline prognosis. Next, Section 2.3 presents the measure prognosis. Finally, Section 3 gives an overview of the injury accidents saved and the results from the cost-benefit analysis.
2.1 The reference year

The reference year considered is 2002. The reference year describes the traffic performance (exposure) and road safety situation of a region in the starting year of the analysis. Due to data scarcity, only highways in Flanders are considered. Traffic performance in this paper is defined as the number of motorized vehicle kilometres on highways. This number is calculated by multiplying the length of the highway segment and the number of vehicles passing by that segment and the total on all highway segments serves as the regional traffic performance. The regional traffic performance is expressed in thousands as 43.8km (1000s).

For now, the road safety situation is only reflected in terms of the number of injury accidents. It should be noted that the number of injury accidents is in reality higher than shown in official statistics because not all accidents are reported and registered by the authorities (Elvik and Vaa, 2004). To better reflect reality, underreporting factors of the injury accidents are used. These are factors by which a registered road safety quantity is multiplied in order to obtain a better approximation of the actual road safety quantities. Different highway segments have different underreporting levels (Reurings et al., 2007). Hence, data on underreporting factors are required per highway segment, yet not available. In this paper, it is assumed that all highway segments have the same underreporting factor. In particular, 1.75 (Elvik and Mysen, 1999) is utilized as a factor with which the registered number of injury accidents on all highways is multiplied. Adjusting for underreporting results into 8,954 injury accidents at the regional level in the reference year. In addition to injury accidents, the road safety situation in the reference year can be reflected by the accident risk. By dividing the adjusted injury accidents by the traffic performance in the region, the accident risk is computed as 205. This indicates that in 2002 approximately 205 injury accidents occurred per 1000 kilometres driven on highways.

Subsequent to the reference year is the baseline prognosis in which changes in traffic performance and autonomous risk are taken into account.

2.2 Baseline prognosis

In this section, baseline prognoses are discussed. First, with respect to the baseline risk for injury accidents, followed by the baseline for traffic performance and lastly the baseline for injury accidents. In this paper, interest is in evaluating road safety measures up to 2010. Therefore, eight baseline years are considered (2003-2010).

2.2.1 Baseline risk for injury accidents

The baseline risk for injury accidents, $br_t$ on highways in year $t$ is determined by the injury accident risk in the reference year, $r_c$, and the autonomous risk change in that year, $f_t$ as: $br_t = f_1 * f_2 * ... * f_t * r_c$. The autonomous risk refers to the collective learning process caused by the growing knowledge of the road safety problem, the constant improvement of the safety performance of the road transport system, better equipped motor vehicles and roads, improvement of road safety education and, increasing legislation and enforcement (COST329, 2004). The change in autonomous risk is quantified as 0.9551 using time series data of the number of casualties (1970-2006) in Belgium (FOD Economie, 2008). This decrease is assumed constant during the years following the reference year. In other words, the baseline risk for injury accidents is expected to decrease by 0.0449 (1-0.9551) each year due to the collective learning process. Starting from 2003 to 2010, the baseline risk for injury accidents is obtained as 196, 187, 178, 170, 163, 155, 148 and 142 respectively. Note that the baseline risk for injury accidents decreases with time due to the declining rate of the autonomous risk.
2.2.2 Baseline for traffic performance
Traffic performance changes over time. This change is incorporated into the model assuming that all highway segments have the same growth rate in traffic performance each year. The data used to compute the growth factor in traffic performance on highways (1.0176) relate to the period 1985–2006 (FOD MV, 2008). In other words, traffic performance on highways is expected to grow by 1.76% each year. The traffic performance, $TP_t$, in year $t$ is given by:

\[ TP_t = TP_{tg} * g_t * TP \]

with $TP$ and $g_t$ being the regional traffic performance on highways in the reference year and the growth factor in traffic performance in year $t$. The traffic performance is respectively calculated as 44.5, 45.3, 46.1, 46.9, 47.7, 48.6, 49.4 and 50.3 (1000s km) for the period 2003, 2004…2010.

2.2.3 Baseline for injury accidents
Based on the baseline risk for injury accidents and traffic performance obtained in Sections 2.2.1 and 2.2.2 respectively, the model predicts the baseline for injury accidents in various baseline years at the regional level. These represent the amount of injury accidents if no regional or locational measures are taken. The baseline for the number of injury accidents, $b_{IAs_t}$ in year $t$ is given by:

\[ b_{IAs_t} = b_{IAs} * TP_t \]

This results in 8,702; 8,458; 8,220; 7,990; 7,766; 7,549; 7,337 and 7,132 in the period 2003, 2004…2010 respectively. Based on the predicted baseline injury accidents, it is deduced that if no regional or locational measures are applied, the baseline injury accidents decrease at an approximate rate of 2.81% per year. These results depend on the growth in traffic performance on the one hand and the autonomous risk change on the other hand. If the growth in traffic performance outweighs the decline in the autonomous risk per year, an increase in injury accidents is realized and vice versa. In this case, the decline in autonomous risk (-4.49%) is higher than the growth in traffic performance (1.76%) per year for the period 2003–2010 causing a decreasing trend in injury accidents. Apart from the regional figure, the baseline for the number of injury accident in year $t$ on a specific highway segment can be obtained by multiplying the regional baseline risk for injury accidents and the traffic performance on that highway segment in that year.

2.3 Measure prognosis
In this phase of the model, the effectiveness of measures on the number of injury accidents is assessed. Two types of measures are distinguished in the model: regional and locational measures. Regional measures have an effect on road safety in the entire region. However, certain measures can only be implemented at locations as it may be very expensive or unnecessary to be applied in the entire region. Such measures are termed locational measures and only have an effect at the location(s) they are applied. The procedure used to calculate the effectiveness of measures on injury accidents is described in the next section.

2.3.1 Computing the effectiveness of measures
To determine the effectiveness of a measure(s), its modification factor for injury accidents is required. The modification factor is the expected proportion of the injury accidents remaining after the measure is applied. The methods used to estimate the effectiveness of one or several measures are illustrated. First, the computation for the effectiveness of a single measure is described (Section 2.3.1.1) after which the procedure for estimating the combined effect is explained. Two methods are described for estimating the combined effect of road safety measures: the accident modification factor method (Section 2.3.1.2) and the dominant common residuals method (Section 2.3.1.3). The term “residuals” refers to the accidents that remain after a measure has taken effect (so this is the same as the modification factor). The
2.3.1.1 Effectiveness of a single measure
Let $E_{lAs}$ denote the effectiveness of a regional measure applied on injury accidents. This implies a modification factor of $1 - E_{lAs}$. Starting from the number of injury accidents computed in the baseline, the remaining injury accidents, $IAs_t$, in year $t$ after applying a regional measure are obtained as: $IAs_t = b \cdot IAs_t \cdot (1 - E_{lAs})$. The number of injury accidents saved is obtained as: $b \cdot IAs_t - IAs_t$.

2.3.1.2 The accident modification factor method
This method assumes that the first order effect of a measure is independent of the first order effect of any other measure and remains unchanged on introducing other measures. The first order effect is the effect each measure has when it is the only measure having an effect and everything else is unchanged. This is an often used method. With this method, the remaining injury accidents, $IAs_t$, after applying $P$ regional measures in year $t$ are obtained as: $IAs_t = b \cdot IAs_t \cdot (1 - E_{lAs,1}) \cdot \ldots \cdot (1 - E_{lAs,P})$.

In practice, measure effects will not be entirely independent in a lot of cases. One measure could influence some of the risk factors that are the targets of another measure, thus reducing the expected effects. For example, this is likely to apply to measures that influence speed, since speed is a risk factor for many accidents (Elvik, 2008). To account for this, another method, termed the dominant common residuals method, is presented.

2.3.1.3 The dominant common residuals method
This method assumes that the most effective measure in a set has a dominant effect that weakens the effects of the measures it is combined with. In this case, $IAs_t = b \cdot IAs_t \cdot [(1 - E_{lAs,1}) \cdot \ldots \cdot (1 - E_{lAs,P})]^{(1 - E_{lAs,P})}$ with $P$ being the most effective measure in the set. Compared to the accident modification factor method, the combined effect of measures estimated using the dominant common residuals is smaller, thereby reflecting the substitution effect of measures. In this paper, the dominant common residuals method is applied in 2006 regarding the combination of signs showing recommended speed in curves and new guardrails along embankments. However, the methods can be extended to other and as many measures as possible.

2.3.2 The assessed measures
In this paper, eight measures obtained from international and regional sources (Elvik and Vaa, 2004; Ministerie van de Vlaamse Gemeenschap, 2007) are examined for the period 2003-2010. They comprise one regional measure and seven locational ones. The regional measure is alcohol or drugs checks applied in 2003 and the locational ones include automatic warnings of queues with variable signs taken at nine highway segments in 2004, congestion warning signals implemented at eight highway segments in 2005, a combination of signs showing recommended speed in curves and new guardrails along embankments taken at 21 highway segments in 2006, fog warning signals applied in 2007 at eight highway segments, more stringent road works warnings on two-lane roads in 2008 at 11 highway segments and scent signals to frighten game in 2009 at 10 highway segments. A measure is applied on the proportion of injury accidents related to it. For example, alcohol or drug checks are applied on injury accidents related to alcohol or drugs. Table 1 lists the measures with the respective years of implementation and the effectiveness in terms of a specific category of accidents.
(average and confidence interval). In 2010, only the effect of the growth in traffic performance and the change in autonomous risk are taken into account.

Table 1: Measures and effectiveness

<table>
<thead>
<tr>
<th>Measure; Year of implementation</th>
<th>Effectiveness (Confidence interval %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol or drug checks; 2003</td>
<td>Reduce IAs related to alcohol or drugs by 25% (-32,-18)</td>
</tr>
<tr>
<td>Automatic warnings of queues with variable signs; 2004</td>
<td>Reduces IAs involving rear-end collisions by 22% (-29,-13)</td>
</tr>
<tr>
<td>Congestion warning signals; 2005</td>
<td>Reduce IAs involving rear-end collisions by 16% (-23,-11)</td>
</tr>
<tr>
<td>Signs showing recommended speed in curves and new guardrails along embankments; 2006</td>
<td>Signs reduce IAs in curves by 13% (-22,-2)</td>
</tr>
<tr>
<td>Fog warning signals; 2007</td>
<td>New guard rails reduce IAs in the event of running off the road by 47% (-52,-41)</td>
</tr>
<tr>
<td>More stringent road works warnings on two-lane roads; 2008</td>
<td>Reduce IAs related to fog by 84% (-93,-63)</td>
</tr>
<tr>
<td>Scent signals to frighten game; 2009</td>
<td>Reduce IAs at road works by 40% (-65,-5)</td>
</tr>
<tr>
<td></td>
<td>Reduce IAs involving game by 70% (-90,-5)</td>
</tr>
</tbody>
</table>

IAs = Injury accidents

3 NUMBER OF INJURY ACCIDENTS SAVED AND COST-BENEFIT ANALYSIS

This section demonstrates the evaluation of the measures. Only results of alcohol or drug checks in 2003, automatic warnings of queues with variable signs in 2004 and the dominant common residuals method in 2006 are illustrated. The same procedures apply to the other measures. Table 2 summarizes the results. The total number of injury accidents saved by 2010 results from the sum of injury accidents saved in the previous years (2003-2010).

3.1 Alcohol or drug checks – 2003

Before implementing measures in 2003, the effect of the change in autonomous risk and growth in traffic performance on the number of injury accidents in the region is taken into account. The total number of injury accidents in the region in the reference year is 8,954 (Section 2.1). The change in the autonomous risk and growth in traffic performance in 2003 are applied on 8,954 and the injury accidents in the region reduce to 8,702 (Section 2.2.3). The injury accidents saved due to the change in autonomous risk and growth in traffic performance is calculated as; 252 = 8,954-8,702. Alcohol or drug checks which reduce injury accidents related to alcohol or drugs by 25% (Table 1) are then evaluated at the regional level in 2003. The proportion of injury accidents related to alcohol or drugs is obtained from literature as 7.69% (National Highway Traffic Safety Administration, 2005). The number of injury accidents related to alcohol or drugs in 2003 is 669=7.69%*8,702. The number 502 (669*0.75) represents the remaining injury accidents after applying alcohol or drug checks (Section 2.3.1.1). The saved injury accidents related to alcohol or drug checks after applying the measure is 167 (669-502). 419 (252+167) is the total number of injury accidents saved due to the change in autonomous risk, growth in traffic performance and the regional measure. 419 is deducted from the total number of injury accidents in the region in the reference year to obtain the remaining injury accidents in the region in 2003 i.e. 8,535 = 8,954–419. This is used as a starting point for the year 2004 in which automatic warnings of queues with variable signs are implemented.
3.2 Automatic warnings of queues with variable signs – 2004
This measure is applied at nine highway segments in 2004 and reduces injury accidents involving rear-end collisions by 22% (Table 1). Of the total injury accidents, 19.81% are related to rear-end collisions (Wang et al., 1999). Before implementing the measure, the change in autonomous risk and growth in traffic performance in 2004 are taken into account. These two factors are applied on 8,535 to yield 8,295 (Table 2). The number of injury accidents saved due to the change in autonomous risk and the growth in traffic performance is 240 (8,535-8,295). The number of injury accidents that occur as a result of rear-end collisions (1,643) in the region in 2004 is then obtained as 1,643 (8,295*19.81%). Automatic warnings of queues with variable signs are then applied at the highway segments i.e. the number of baseline injury accidents on each of the highway segments are multiplied by 0.78 and the rear-end injury accidents reduce from 1,643 to 1,598. The number of rear-end injury accidents saved after applying automatic warnings of queues with variable signs is obtained as 1,643-1,598 = 45. The total injury accidents saved in 2004 is 240+45 = 285. The total number of remaining injury accidents in the region in 2004 after applying the autonomous risk change, the growth in traffic performance and automatic warnings of queues with variable signs is 8,535-285 = 8,250. This serves as the starting point of year 2005.

3.3 The dominant common residuals method – 2006
The dominant common residuals method is applied in 2006 for the combination of signs showing recommended speed in curves and new guardrails along embankments. Signs showing recommended speed in curves reduce injury accidents in curves by 13% and new guardrails along embankments reduce injury accidents in the event of running off the road by 47% (Table 1). The product of the modification factors of both measures is raised to the power of the modification factor of the most effective measure. This results into a combined effect of 0.34 (1-[0.87*0.53]0.53) and a modification factor of 0.66 (1-0.34) (see Section 2.3.1.3). In other words, when taken simultaneously, these measures reduce injury accidents by 34%. The proportion of injury accidents related to the measures is obtained from literature as 21.75% (Elvik and Vaa, 2004; Comte and Hamson, 2000). These are the injury accidents on which the measures are applied in 2006. The procedure utilized for automatic warnings of queues with variable signs (Section 3.2) is repeated here to obtain the number of injury accidents saved. Table 2 summarizes the number of saved injury accidents with respect to the autonomous risk change, the growth in traffic performance and the measures.

3.4 Overview of injury accidents saved
On the whole, 2,167 (24.20%) injury accidents are saved by 2010. Of these, the measures contributed to 400 (4.47%) accidents while 1,767 (19.73%) saved accidents were attributed to the change in autonomous risk and the growth in traffic performance.

In the next section, the results of the cost-benefit analysis are presented. All measures with a cost-benefit ratio greater than 1 yield more benefits than they cost. A ratio below 1 indicates negative cost effectiveness.
### Table 2: Summary of injury accidents saved 2003-2010

<table>
<thead>
<tr>
<th>Measure; Year of implementation</th>
<th>Regional IAs in previous year</th>
<th>Regional IAs after AR, GTP</th>
<th>Regional savings (%) after AR, GTP</th>
<th>Number of IAs related to measure</th>
<th>Remaining IAs after applying measures</th>
<th>Savings (%)</th>
<th>Remaining IAs in region after AR,GTP, measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol or drugs checks; 2003</td>
<td>8,954</td>
<td>8,702</td>
<td>252 (2.81)</td>
<td>669</td>
<td>502</td>
<td>167</td>
<td>419</td>
</tr>
<tr>
<td>Automatic warnings of queues with variable signs; 2004</td>
<td>8,535</td>
<td>8,295</td>
<td>240 (2.81)</td>
<td>1,643</td>
<td>1,598</td>
<td>45</td>
<td>285</td>
</tr>
<tr>
<td>Congestion warning signals; 2005</td>
<td>8,250</td>
<td>8,019</td>
<td>231 (2.81)</td>
<td>1,588</td>
<td>1,558</td>
<td>30</td>
<td>261</td>
</tr>
<tr>
<td>Signs showing recommended speed in curves and new guardrails along embankments; 2006</td>
<td>7,989</td>
<td>7,765</td>
<td>224 (2.81)</td>
<td>1,689</td>
<td>1,565</td>
<td>124</td>
<td>348</td>
</tr>
<tr>
<td>Fog warning signals; 2007</td>
<td>7,641</td>
<td>7,427</td>
<td>214 (2.81)</td>
<td>41</td>
<td>36</td>
<td>5</td>
<td>219</td>
</tr>
<tr>
<td>More stringent road works warnings on two-lane roads; 2008</td>
<td>7,422</td>
<td>7,213</td>
<td>209 (2.81)</td>
<td>172</td>
<td>164</td>
<td>9</td>
<td>217</td>
</tr>
<tr>
<td>Scent signals to frighten game; 2009</td>
<td>7,205</td>
<td>7,002</td>
<td>202 (2.81)</td>
<td>350</td>
<td>330</td>
<td>20</td>
<td>222</td>
</tr>
<tr>
<td>AR,GTP; 2010</td>
<td>6,983</td>
<td>6,787</td>
<td>195 (2.81)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>195</td>
</tr>
<tr>
<td>Savings by 2010</td>
<td>1,767</td>
<td>1,676</td>
<td>(19.73)</td>
<td>400</td>
<td>2,167</td>
<td>(4.47)</td>
<td>(24.20)</td>
</tr>
</tbody>
</table>

IAs = Injury accidents  AR = Autonomous risk change  GTP = Growth in traffic performance  NA = Not applicable

**3.5 Cost-benefit analysis**

This analysis is designed to identify best policy options for which benefits are much greater than costs. This is realized using cost-benefit ratios being the ratio between the cash value of benefits and costs. To determine the benefits of the applied measures, the value of an avoided injury accident expressed in euros is required. The utilized value in this paper is 10,000 euros (European road safety observatory, 2009). In addition, the cost of the applied measures per kilometre must be known to compute the total cost of the applied measures. The measure
costs (euros) are obtained from literature (Verstraete, 2000; Elvik and Vaa, 2004). Finally, a discount rate is required to express the costs and benefits in terms of the nominal value of the reference year and a discount rate of 4% is used for this (SWOV, ECORYS, TNO and MNP, 2008; Elvik et al., 2009).

The average benefit-cost ratio of all implemented measures is 34. This means that each euro spent to prevent an injury accident implies a saving of 34 euros on average. In addition, the benefit-cost ratios are computed per year as 13, 74, 46, 6, 10, 14 and 72 for 2003, 2004…2009 respectively. According to the theory underlying cost-benefit analysis (Elvik, 2007), it is appropriate to adopt all measures since they yield greater benefits than costs. However, it is sometimes not appropriate to fully base road safety policy on cost-benefit analyses. The objective might be to give priority to those measures that provide the largest reductions in the number of road accidents. In this case, alcohol or drug checks and, the combination of signs showing recommended speed in curves and new guardrails along embankments would be given priority (see Table 2). These measures are not the most cost-effective and policy priorities may depart from the results of cost-benefit analyses (Elvik, 2007). Given that the aim here is to identify the most cost-effective measures, a cost-benefit analysis justifies the choice between measures. In this situation, automatic warnings of queues with variable signs, scent signals to frighten game and congestion warning signals should obtain priority.

So far, the number of injury accidents saved in 2010 is computed taking the effect of autonomous risk change, growth in traffic performance and eight measures into account. However, these results are based on a set of assumptions. Therefore, uncertainty analysis is carried out in the next section to examine the robustness of the output. Through this analysis, possible influences of input factors (such as the constant underreporting factors, growth factors in traffic performance, modification factors for the autonomous risk and the independence versus dependence of measure effects, effectiveness of measures) on the results and conclusions drawn from the model can be investigated.

4 UNCERTAINTY ANALYSIS
Since the number of injury accidents saved can largely be influenced by the decisions taken earlier in the model, their robustness needs to be assessed. In other words, the stability in the output given small changes in the input is tested. This is achieved using uncertainty analysis. Section 4.1 describes some theoretical considerations whereas the results are presented in Section 4.2.

4.1 Theoretical considerations of the uncertainty analysis
Generally, uncertainty analysis estimates the uncertainty in the model output taking into account the uncertainty in the model input factors. Instead of one result, a distribution of values and descriptive statistics such as the mean and standard deviation describe the features of the estimated output (Saltelli et al., 2004). A description of steps to perform for this kind of analysis, independently of the method being used, is given in Saltelli et al. (2004). The following steps are taken to assess the robustness of the model results in this paper.

First, the goal of the analysis and the form of the output function should be established. The output of interest is a single value that provides the top-most solution to the question being investigated. In this case, the output of interest is the number of injury accidents saved by 2010 due to the eight road safety measures and accounting for autonomous risk change and the growth in traffic performance.

Next, the input factors to include in the analysis are decided on. As stated above, the input factors considered here comprise underreporting factors, growth in traffic performance, change in autonomous risk, effectiveness of measures and the (in)dependence of measures.
Subsequently, a distribution function for each of the input factor needs to be chosen. The distributions are based on common knowledge. The truncated normal distribution is chosen. An advantage of this distribution is that the sampling of unwanted values can be avoided.

Afterwards, the input sample is generated. A random sample N of 1000 values is generated for each input factor using a truncated normal distribution. This results in a sample of size N (number of runs) by M (number of input factors). Consequently, the model is assessed on the generated sample and an output produced. Each of the N runs is converted into one output value, that is, a given number of saved injury accidents. In the end, 1000 output values are produced and their average taken. The average number of injury accidents saved by 2010 is the output of interest.

Lastly, the model output is analyzed and conclusions drawn. The distribution of the output indicates the variability in the number of injury accidents saved with respect to the different input factors. The uncertainty analysis results are discussed in the next section.

4.2 Results of the uncertainty analysis

The distribution of the injury accidents saved is displayed by the histogram in Figure 1. The average number of injury accidents saved is 2,200 with a standard deviation of 286, a minimum of 1,319 and a maximum of 3,139. The wide range of the number of injury accidents saved (1,319 to 3,139) implies a high uncertainty caused by a change in the input factors. In the future, the factors causing most uncertainty in the injury accidents saved will be identified. That way, the impact of a change in input factors on the number of injury accidents saved becomes clear as well as the most influential factors for which the best options need to be chosen in order to obtain a robust output.

Figure 1: Distribution of injury accidents saved by 2010

5 DISCUSSION, CONCLUSION AND FUTURE RESEARCH

The objective of this paper is to present a model assessing the impact of a set of policy measures on road safety at the regional level. Special attention is devoted to the combined effect of several measures introduced at the same time. Until now, the accident modification factor method is often used. This method assumes that a measure effect is independent of the effects of any other measure it is combined with. However, measure effects are not always independent. Measures can influence some of the risk factors that are the targets of other
measures, thus reducing their likely effects. To account for this, the dominant common residuals method is applied. The idea underlying this method is that the most effective measure in a set dominates the others by partly or fully influencing the same group of accidents or the same risk factors. In addition to the combination of measures, effectiveness of single measures is illustrated. The RRSE model developed by SWOV (Reurings and Wijnen, 2008) is used as a starting point. The main outputs of the model are the number of injury accidents saved and the cost-benefit ratios of the measures taken. By 2010, 2,167 injury accidents are saved. Approximately 400 of these are due to the measures taken; the other savings (1,767) can be attributed to the autonomous risk change and the growth in traffic performance. The high number of injury accidents saved due to the change in autonomous risk and the growth in traffic performance seems to indicate that these factors are so effective that no additional road safety measures need to be taken. However, it should be noted that the autonomous risk utilized in this case is approximated using the past evolution in the number of casualties and is no guarantee for a similar change in the future. Cost-benefit analysis indicates that it is appropriate to adopt all measures since they yield greater benefits than costs. Given the assumptions of the model, uncertainty analysis is carried out to examine the robustness of the output. The analysis shows that small changes in the estimates of the input factors cause a large amount of uncertainty in the number of injury accidents saved. Hence, more knowledge concerning the input factors is required to reduce the variability in the output.

The model presented here can assist regions to assess the road safety effects of both regional and locational measures applied in various years. In this respect, the interdependence between measures can be accounted for. Moreover, aggregated results can be obtained and decisions regarding cost-effective measures supported. At the same time, some limitations of the current model can be mentioned. One weak point is the data used. Detailed data describing the road safety and traffic performance in the whole region of Flanders are scarcely available. The present results are based on road safety and traffic performance data of highways in 2002. 2002 as the reference year does not depict the present road safety picture as in the meantime many developments which affect road safety have taken place. However, these best available data are useful for the purpose of illustrating and fine-tuning the methodology. Other limitations deal with the assumptions considered at this point. For example, the change in autonomous risk and the growth in traffic performance are presumed constant over time and the degree of underreporting equal on all segments. Nevertheless, they have been partly captured through uncertainty analysis. Apart from this quantification of the variability in the number of injury accidents saved, the impact of such model assumptions will be assessed in future research by means of a sensitivity analysis. Through this analysis, the input factors that largely influence the output variance will be identified and their effect quantified. That way, the most influential factors, for which a decision needs to be taken in order to obtain a robust output, can be identified.

In addition to the sensitivity analysis, the following areas will be tackled in future research: the dependency between measures reinforcing each other will be studied, the model will be linked to a geographical information system to display the most unsafe areas in the region, the data set will be extended (including more road and intersection categories) and the effects of environmental and health measures on road safety will be assessed.

6 REFERENCES


1. Abstract

The evaluation and rating of the safety of traffic roads has a long tradition, because it is essential to visualize safety lacks and help decision makers to choose the best spots to rebuild and improve. Early approaches to road scoring used accident data, whereas new approaches, like the Star Rating from EuroRAP, use information gathered through special inspections. The common ground of existing methods is the approach to divide the road into sections of different lengths and to evaluate a score for these sections.

Our approach is based on data that is gathered through a Road Safety Inspection. The main novelty is that the road is not divided into sections to look how many safety hazards are on one section, but that each detected hazard influences the safety value of its very spot. So the final road evaluation has a granularity of about 10 meters. A further improvement is the distinction between active and passive safety hazards, where the first affects the accident risk while the latter affects the severity of an accident.

This paper is intended as a starting point of work, since a complete new approach is introduced. Much research has to be performed to evaluate the approach itself on the one hand, and to find the best values and settings to model the real safety risk on the other hand.

2. Introduction

New computer technologies are applied very fast in most business fields, while the progress in public funded areas is normally much slower. In the field of road traffic safety, the same circumstances can be noticed. This paper is the effort of a computer scientist to enhance the use of computers and computer techniques in the field of road safety research, in particular the road safety scoring.

First, the state of the art is described, which includes the accident based generated risk maps for higher roads and the relatively new method of star rating which considers the road design and its condition. Afterwards our own approach is described, which also looks at the road design independent from accident data, where the main improvement is the rating algorithm that allows precisely accurate scoring, rather than long sections with overall scores.

The paper is closed with a conclusion, and an outline of the much future work, that has to be done in this research field.
3. State of the Art

The most modern application regarding road safety scoring is the so called Road Assessment Programme, which is implemented on all continents in various scopes. The European Road Assessment Programme (EuroRAP)\(^1\) [Lynam et al., 2004] was piloted in 2001, as a sister program to the European New Car Assessment Programme (Euro NCAP), in four countries and has now launched in twenty European countries. The methods used by EuroRAP are also applied in Australia through AusRAP and in the United States through usRAP. Furthermore, the know-how gained at the most advanced programmes are being transferred to Africa, Asia, and Latin America by the international Road Assessment Program (iRAP).

EuroRAP aims to provide independent, consistent safety ratings of high-risk roads across borders where large numbers are killed or seriously injured and to identify affordable high-return countermeasures. The aim has been to cover a network of interurban roads on which at least 30% of national fatalities occurred. The pilot programme was planned in three parts:

- general international comparisons of death rates on the road network in different EU countries,
- analysis and mapping of fatal and severe accident rates on major roads outside built-up areas,
- inspection of the safety quality of the road infrastructure to identify to what extent they protect road-users from accidents and from death and serious injury when accidents do occur.

Within this framework Risk Maps were introduced and developed that allow the identification of higher risk routes and enable performance tracking over time and detailed analyses of accident patterns on different roads. Furthermore, road inspections led to the current Road Protection Score, which focuses on assessing the quality of the road infrastructure.

Risk Maps

EuroRAP uses accident data to provide risk ratings in form of maps showing the density of traffic collisions that caused death and life threatening injuries. They highlight sections of road where intervention may be required to reduce the likelihood of collisions.

Two types of risk maps are presented. The first plots the annual average number of fatalities per road kilometre, is referred to as the 'collective risk map' and presents the crash density. The second type of maps plot the number of crashes per vehicle kilometre travelled and are referred to as 'individual risk maps', as they show the risk for individual drivers, calculated by dividing the frequency of crashes per annum by the distance travelled on each road link per annum [Smith, Daly and McInerney, 2007, p. 3].

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\(^1\) [http://www.eurorap.org/](http://www.eurorap.org/)
**Road Protection Score and Star Ratings**

Within the scope of EuroRAP, road inspections are carried out with the aim to produce a score for each route section that enables it to be compared with other sections. This *Road Protection Score* (RPS) focuses on the road design and on road-based safety features. The required data is recorded by in-car assessors using a tablet linked to a GIS database (see Figure 2).

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Figure 1: Risk map of Austria for the years 2001 - 2003

2 http://www.eurorap.org/risk_maps
The scoring software takes the data directly from the database and presents the RPS results in form of star-rated maps. The used Star Rating is based on the RPS, where one to five stars are awarded to road links, depending on the potential quality of the road infrastructure (see Fel! Hittar inte referenskälla.). The RPS can be presented in the aggregate for all accident types or for individual accident types (head-on crashes, run-off road etc.) showing the different ratings along the route.

In its current form the RPS does not include the likelihood of an accident occurring: currently “protection” refers only to the protection from injury when accidents happen [Lynam et al., 2007, p. 41]. Thus a high score will not necessarily reflect a low accident rate, as only part of the risk is being scored. It should rather demonstrate that for a given number of accidents, a lower proportion of them would result in fatal or serious injury.

But a second component is being added to the rating system, which includes road infrastructure features that affect accident likelihood. The two factors will be combined in a risk matrix to provide an overall assessment of risk [Lynam et al., 2007]. The use of a risk matrix is a technique commonly used in risk assessment. It enables total risk to be seen as the combination of the likelihood of an event (accident) occurring, and the resulting potential consequence (injury severity). Reducing the effect of either factor alone, or of both together can reduce the total risk. To use this approach in the RPS, the component factors, which contribute to the variables on each axis, have to be defined and assigned with a risk relative to each other. For example, roads with wide lanes (greater than 3.6m wide) receive a better score than roads with narrow lanes (less than 2.8m wide), as they leave more room for error than the latter where the risk of a crash is 50% higher. Or, roads with wide sealed shoulders (greater than 2.4m) receive a better score than roads with no sealed shoulders where the risk of a crash is 60% higher [AusRAP, 2008, p. 7].

The ratings for each individual component will still be identifiable so that the engineer knows which aspect of the infrastructure needs improving. Such a combined assessment is already used in AusRAP, although the two components are not distinguished separately.

iRAP set its focus also on developing the rating system further. In many countries, the number of pedestrian deaths is high on both urban and rural roads. This requires the rating to be extended in two ways – both to take account of urban environments, and to consider the likelihood and protective factors associated with vulnerable road users, particularly motorcyclists. Research information on these factors in terms of their influence on risk is less extensive than that pertaining to car occupants, and the linkage between vehicle and road design is less clear, so these developments remain a difficult challenge but will form one aspect of future EuroRAP work [Lynam et al., 2004].

The particular focus that RPS provides together with the simply rating by accident numbers or rates, highlights the extent to which observed high accident numbers result from poor quality of the road design.
Figure 3: Star rating for the major roads in Ireland
4. Our Approach

Our approach needs, similar to the star rating data gathered through road safety inspections. Those inspections are very cost intensive and therefore not applicable to only score the safety of the road. It is therefore recommended to implement the road traffic safety framework introduced in [Yildiz, 2009] which includes the inspection of the complete road network using an especially for this purpose developed software. Since this software records the information about the detected hazards GPS encoded and in a machine readable form, this data can easily be used for road scoring.

First, the detected safety hazards are classified as active or passive hazards, where active hazards like rain grooves raises the risk of an accident and passive hazards like uncovered bridge piers have no affect on the accident risk, but can worsen the outcome of an accident. The results of the final scoring are therefore two separate road scores, one for active safety and one for passive safety. Each hazard affects the risk value of his very spot and can also affect a specific length of the road before or after its position.

Rain grooves, as an example for active hazards, does not affect the accident risk before their location, but a driver who loses the control over his vehicle during the rain grooves, can either retrieve the control after the rain grooves, or he can slide a while after the rain grooves and can have an accident. An unsecure bridge pier, on the other hand, is a good example for passive hazards. The pier has no affect on accidents that happens after its position but for accidents that happen before the pier, there is a possibility of a collision which decreases with increasing distance.

Besides this distinction, to each hazard a risk value has to be assigned. This value has to be a numerical value between 0 and 100, where 0 is safe, and 100 is unsafe. During the tests, some initial values based on the experience of two road safety inspections experts were used, but a guideline for value determination has to be elaborated. A further distinction is between point hazards and section hazards. Rain grooves are again a good example for section hazards that can be present over a specific length, while the unsecure bridge pier is a point hazard with an exact position.

A simplified example should explain the main principle of our approach. For this example, we do not distinguish between active and passive hazards, so each hazard affects the road before and after its position. We also have only three risk values, 1 for little risk, 2 for middle risk and 3 for high risk. Consider a road of ten kilometers, showed in figure 4. On kilometer two of the road, a point hazard with no risk is present. The point hazard on kilometer four has a middle risk, while the section hazard from kilometer five and a half to kilometer eight has a high risk.

![Figure 4: Safety hazards on the road](image-url)
Each hazard does affect now the risk value of the road on its position and also on the sections before and after. The range of this affection depends on the type of the hazard, while the corresponding risk value on these sections are calculated using a gauss curve in order to model the real world behavior of vehicles. Figure 5 shows the hazards from our example together with their affections ranges.

![Safety hazards with their risk values and affection ranges](image1)

**Figure 5:** Safety hazards with their risk values and affection ranges

The risk values can be calculated on the road for every 10 meters, which is the average error for GPS and therefore the minimum of the possible granularity. So we have for each point on the road several risk values, which now have to be aggregated. On kilometre two for example, we have one point for the low risked hazard, and 0.3 points from the affection range of the middle risked hazard, while the high risked hazard has no affect. This gives a total of 1.3 points for this road point.

![Aggregated risk values for the road](image2)

**Figure 6:** Aggregated risk values for the road
The result is showed in figure 6, where the black line are the aggregated values, and the blue lines represents the final road score. A road point is considered to be middle risked, if its final risk value is between the middle risk value and the high risk value. Figure 7 shows the result of such a road scoring, displayed on a map.

Figure 7: Result of a road evaluation

5. Conclusion and Future Work

We have seen that computer technologies are not applied very comprehensive in the field of road safety research and road safety scoring. The actual most modern approach, namely the star rating as part of the EuroRAP program uses a specific developed tablet where the results are used only for the scoring. This makes the scoring task very expansive and therefore hard to implement on the complete road network.

This can be avoided by implementing road safety inspections in their intended form on the complete road network using the new developed RSI-Software [Yildiz, 2009] and use this gathered data. This also enables one to score the road in more detail with a higher granularity. Our approach uses two aspects of safety hazards the first time for safety scoring, namely its nature as active or passive hazards and its affection range before or after its position on the road.

The scoring algorithm has only be tested on small road sections with only a few different hazard types. The first thing to do in future is to elaborate a guideline to determine the risk value of a hazard depending on its location, its nature and other road design related issues at
this spot. Comprehensive testing is only possible after the road safety inspections are implemented on larger road sections using the referenced software. During these tests also the guideline for risk values should be studied and improved.

6. References


1. Abstract

Road Safety Inspections (RSIs) are a relatively new method to gather safety relevant information about roads. Within the scope of the RIPCORD-iSEREST project, funded by the European Union, a survey involving 14 European countries have been conducted to outline a best-practice guideline for RSIs. The in 2006 published results summarized that RSI is a preventive tool and should be carried out by trained road experts for the whole road network on a regular basis (two to four years) and should result in a formal report, including detected hazards and safety issues.

However, a RSI is very time consuming and therefore cost expensive (estimated 10.000 € per 10 km) [Nast, 2006], and therefore is usually only performed on small road sections with a high accident density. In order to implement RSI’s as they were intended, a software tool, that covers the complete process of a RSI was developed in cooperation with the civil engineer office nast consulting, which carries out RSI’s in Austria.

Field tests have shown that a small team of two to three experts can inspect a section of 200 kilometers including all necessary pre- and post processing tasks within a week. For Austria this would mean that the complete motorway network of 2000 km can be inspected in five weeks by two teams. Considering also the regional distribution, six teams would need about 200 weeks, the intended four year period for RSIs, to inspect the complete upper road network of Austria, containing 38.000 kilometers of motorways, highways and federal roads.

2. Introduction

The main objective of Road Safety Inspections (RSIs) is to monitor existing roads on a regular basis, to identify traffic hazards related to the road environment characteristics, and to propose interventions to mitigate the detected hazards, thus raising the safety level of existing roads. RSI is considered as a preventive tool, because neither its initiation nor its implementation depends on any kind of accident data or knowledge about the safety level of the relevant road. Only general knowledge on road hazards, safety issues related to the road environment, and effective infrastructure interventions are needed.

Nevertheless, in some EU countries accident data is used either to decide which roads to inspect, or as complementary information to elaborate cost-effective treatments. This is mainly due to limited resources and high costs associated with the implementation of RSIs.
Therefore, we can often observe that either only specific road sections or only specific types of roads are actually inspected.

Aimed at developing best-practice guidelines for RSI, a survey involving 14 European countries was conducted within the scope of the EU project RIPCORD-iSEREST to determine the current practices of RSI in Europe. A Common Understanding Approach for RSI was then defined and agreed upon by the participants according to whom RSI is defined as [Moscari and Hollo, 2006, p. 28]:

- a preventive tool,
- consisting of regular, systematic, on-site inspections of existing roads, covering the whole road network,
- carried out by trained safety expert teams,
- resulting in a formal report on detected hazards and safety issues,
- requiring a formal response by the relevant road authority.

RSI is performed on-site and preferably by trained traffic safety experts, to be efficient. They have to identify possible problematic sites upon preliminary analysis of the road to be inspected; identify hazards while moving/driving along the road; evaluate their importance and decide if further information is needed; elaborate cost-effective measures that would mitigate these hazards without causing new ones.

During the inspections, non-conformities, adaptations and improvements according to the state-of-the-art should be taken into account. The current design standards and new methods emanating from generally accepted scientific experiences should be considered as well.

Because RSIs are associated with high costs, the implementations in most of the countries in the European Union (EU) do not comply fully with the guidelines mentioned above. Some EU countries do not use RSI at all. Most of the current road safety activities consist of a mixture of RSA, road maintenance inspections and black spot analysis and intervention [Cardoso et al., 2007].

Therefore, we can say that RSI is recognized as an effective tool for improving road traffic safety in many countries, but its practical implementation differs from country to country, often defined and limited by cost factors. A number of technical, administrative, regulatory, legal, and financial questions have to be solved before each country can adapt the concept in its intended form.

3. State of the Art

Different countries have different approaches for implementing RSI, while Norway seems to be the European country that takes the most effort for RSI. RSI are implemented in Norway since 1999 and the complete implementation was revised in 2005 to improve the method. Details to the actual practice can be found in [Handbook222, 2006]. The main change is, that they pay more attention to the preparing step in order to save time at the reporting step, where some standardized excel forms are used.

In Austria, where EVES has been developed however, pilot RSI was first conducted in the year 2003. The civil engineering bureau nast consulting has carried out several RSI’s. After the section that has to be inspected was defined, as a preparation, the accident map of the section was discussed with local road maintainers to gain information about possible
dangerous spots to be inspected more carefully. The survey was recorded via video tape, while every 500 meters the actual kilometer point was dictated on the tape. Observed hazards were also dictated on the tape. The most time consuming part was the reporting, because the experts had to watch the video tape, estimate the kilometer of a recorded hazard and write everything manually into a word file.

The whole process was not only very time consuming and therefore expensive, but also was the result only a written report which could not used further for analysis. To overcome this shortcomings, nast consulting, worked on a project proposal for the development of a computer-aided system, which has been funded by the Centre for Innovation and Technology (Zentrum für Innovation und Technologie – ZIT). The application fields of the system were considered in two groups, depending on the devices on which the system was supposed to run. For the higher road network, where the inspection is performed in a driving car, the system has to run on a notebook computer. For the lower road network (e.g., bikeways, footpaths, etc.), however, where the inspection is performed on a bike or on foot, the system has to run on a mobile device.

4. Definitions

Before starting with the description of EVES, the meanings of some terms used through the rest of this paper should be clarified.

- **Event**: is a general term describing everything that is registered during the inspection related to the road traffic system’s safety. We do not use the term hazard, as the system can also be used to capture other things than hazards, such as the number of lanes, etc.
- **Project**: comprises the entirety of all tasks related to one inspection on a specified area.
- **Road**: stands for a real road of the road network.
- **Route**: stands for of one or more road sections, describing the part of the road network that is going to be inspected in the scope of the project.
- **Survey**: describes the actual inspection of a passage of the route. In general, at least two surveys are carried out for each project, that is, one survey for each direction of the specified route of the project.

5. The computer aided RSI Software - EVES

In order to give the reader a good overview of the software's functionalities and features, especially those that optimise previous approaches, EVES is explained by considering every step of the inspection workflow: preparations, survey, post-processing, and reporting.

**Using EVES to Define the Data Structures**

As mentioned earlier, it is important to have a well-defined checklist of events that are going to be detected during the survey. This way it is ensured that important events are not overseen and the survey has not to be repeated.

1 http://www.zit.co.at/
Let us assume that one wants to use EVES to detect and register events regarding safety hazards on motorways. Let us further assume that one does not want only the information that a hazard exists, but also additional information, such as its state and what its shortcoming is. The state “overgrown” of an event “vegetation”, for instance, could have shortcomings, such as “causing poor visibility”, or “risk of limbs falling on the road”. For each shortcoming one could define at least one countermeasure to eliminate the shortcoming or its effects.

In order to tell the system what kind of information should be registered for each of the detected events, one has to define its structure to which is referred as its Event Type. For our scenario, one could define an Event Type called “Motorway” with the data structure as depicted in Figure 1.

![Figure 1: Data structure of a sample Event Type „Motorway“](image)

It is clear that the desired data structure (i.e., events and their attributes) could differ from application field to application field. In order to enable EVES to be used for all road and inspection types, one of the main objectives during the development of EVES was to provide utmost flexibility. This objective resulted in the development of several tools within EVES that provide the user with means to easily adapt and use the system for different purposes. In the following the three structural managers that give the user full control over the underlying data structure are described: the Event Type Manager, the Category Manager, and the Module Manager.

**Event Type Manager.** The Event Type Manager allows the user to define Event Types for different purposes. Figure 2 shows the data structure of our “Motorway” Event Type as in the above mentioned example.
With this interface the user can define the data structure of an Event Type, by adding attributes where needed. It allows the user to define several Event Types for different purposes and hence provides a flexible system for handling events from different application fields or survey types (e.g., Bikeways, etc.).

**Category Manager.** After having defined the desired Event Types according to which the user wants to capture events during the survey, he has to enter the events in the checklist into the system. This task is performed using the **Category Manager.** Theoretically, the user could define all the events without defining a single category. However, as the checklists for RSIs are in general very long, the maintenance of such a list would soon get uncomfortable. In order to provide a thematic summarisation of the events, the user has been given the possibility to define hierarchies of categories and to add events wherever desired. Figure 3 shows the user interface to perform these tasks:

With this interface the user can define the needed categories, where the user can also assign icons for the events to be used during the survey. It is also important to declare whether an Event is a *Point Event*, indicating an event at a certain point of the road (e.g., bad positioned traffic sign) or a *Section Event*, indicating an event that lasts along a certain section of the road (e.g., a missing service lane). Further, the user can state whether more than one instance of an event can be registered during the survey at the same time. Let us take the events in the “Speed Regulations” category as example. It is not possible to have more than one instance of this event on a motorway at the same time, because a speed limit sign overrides the previous speed limit (e.g., 70 km/h sign overrides the previous 100 km/h sign).
Figure 3: Sample category structure as defined in the Category Manager

Through this interface the user gets access to the Event Content Manager, where he actually enters the content of the events, that is, its attributes (see Figure 4). The more detailed this work is done, the easier and faster the post-processing and the reporting will be.

Figure 4: Sample event content as defined in the Event Content Manager

Module Manager. Another structural manager that EVES offers to provide maximum flexibility is the Module Manager (see Figure 5). A module is a collection of events and categories that are relevant for a certain sort of inspection. The Module Manager allows the user to define separate modules for motorways, highways, rural streets, construction sites, or for inspections for night-time, different weather conditions, etc. For each module the user composes a graphical board that contains the icons of the events and categories of this module.
After the data structures have been set, the user can begin to prepare for the survey. Note that the steps explained so far are the steps that have to be undertaken only once after the installation of EVES and occasionally when EVES is going to be used for different tasks.

**Using EVES for the Preparation of Inspections**

The first thing to do before carrying out a survey is to create a project for the inspection. Besides general information about client, the person in charge, route to be inspected etc. the user has to select the modules he wants to use for inspection and, optionally, to load the map of the area where the inspection will take place. The current position of the user is displayed during the survey. However, the main function of the map is to integrate and highlight so called *Points of Interest* (POIs) (see Figure 6), which are basically predefined spots on the road that the user wants to be reminded of during the survey, such as black spots already identified by other authorities or the user's own POIs, which can be automatically imported into the system using GPS information. The system gives an acoustic signal with an optional written explanation when a POI is approached and is as close as 100 metres.

The system is build for two-way roads, where for each direction a separate survey is conducted. On one-way roads the second direction can be ignored. For each direction more than one survey can be performed and the captured events can afterwards be merged into one single survey, if it is not possible to register all relevant information in one thoroughfare.
Using EVES for Road Safety Inspections

The road survey with the traditional approach is a time consuming and therefore expensive task. Therefore, the main motivation to develop a computer-aided RSI system has been to assist road inspection engineers in every possible way to ease and speed-up the process, hence reducing costs.

There are many ways of presenting the user the predefined events for him to register when detected. The first user design element thought of was the “outlook menu” to represent predefined categories, where clicking on the item would open up the menu revealing its content, that is events and other subcategories. However, after conducted a few test runs with this design, it was concluded that outlook menus are not convenient to use, because the user has to read the labels of the hazards and subcategories to find his way through the menu structure to the correct event he detected on the road and wants to register into the system, which is time consuming and therefore not appropriate to be used during the inspection where the car is moving fast and the engineer has to pay attention to the road in order not to miss other events.

For the second attempt, numerical codes were used for categories and events, with the limitation of maximal three subcategory levels and nine elements at each level. This way each event has been given a unique four-digit numerical code to be identified with during the survey. The main objections against this method have been the loss of flexibility as a result of the stated limitations regarding the structuring and numbering and the required training to memorise the codes before the survey. Even allowing voice commands for predefined event names or numerical codes demonstrated not applicable during a real survey.

All these attempts lead to the conviction that a well-defined graphical user interface with context menus and icons for events or event categories is the most appropriate way.
The main goal during the survey is to allow a quick interaction of the road inspection engineer with the system, so that he can still concentrate on the road. With the introduced graphical modules this goal is achieved as the main module board contains only the most needed elements. It is also possible to record an audio memo for the last registered event with an easy key stroke, so the time the engineer has to look on the screen is minimised, which in turn maximises the time he can concentrate on the road to detect events.

![Figure 7: Graphical User Interface of EVES during a survey](image)

Figure 7 shows the graphical user interface for the survey task. The area on the right side contains the map and GPS data, only for information purposes, and more importantly the list of already registered events. Whenever an event is registered, its label appears in the tab “Active Events”. If it has been defined as point event, it is moved to the tab “Inactive Events” after a specified time, which gives the engineer enough time to record audio memos if necessary. If it has been defined as a section event, however, it remains in the tab for active events till the user indicates its end by simply clicking on the event's label, which assigns the event with the endpoint of the section and moves it to the tab for inactive events. It is further possible to record more than one audio memo for events, no matter if active or inactive, by either clicking on the record button beside the event's label or entering a key shortcut.

Once the end of an inspection for a certain section is reached, the survey can be saved and closed and a new survey on the same section in both directions can be started. As mentioned before, it can be necessary sometimes to drive through a section more than once, especially if the checklist contains too many events so the road engineer is overstrained. The events that are registered in different surveys can later be merged during post-processing.

**Using EVES for Post-processing**

After the inspection task itself, post-processing is the second important task of a RSI, which is very time consuming if undertaken with traditional state-of-the-art methods. Therefore, one of the main motivations to develop EVES has been to address this problem. Providing a computer-aided RSI system and consequently having registered the data in an electronic and structural form already brings about a great benefit compared to traditional
methods, where the survey is usually being recorded on video tape and has to be watched through in order to enter the information into the computer. However, EVES provides further features to ease the task of controlling and editing the registered information if necessary.

**Preparations before post-processing.** Having finished the survey, there is some optional work to do before starting with the actual post-processing. First, if the map of the inspected area was not downloaded before, it should be downloaded at this point. Even though the map is still not an obligatory element, it is very useful during the post-processing and the reporting afterwards, because it gives the user a good visual overview of the location of the events.

The second preparation task concerns the visual data recorded on videotape during the survey. In general, one tape is used for the whole inspection, so there can be several surveys on one tape. Therefore the video has first to be converted into a digital format and has to be cut and assigned to its respective part of the survey.

Another preparation task concerns the correction of the inspected road course. Because GPS signals have a known inaccuracy of about 15 metres, the registered course can lay several meters aside the real course of the road. If the user has digital road data from a supplier, like Teleatlas\(^2\), in form of a geospatial database, EVES can map the registered course to the real course automatically. Because some parallel roads lie very close to each other, the error in the GPS accuracy can lead to incorrect road selections during the mapping process. In such cases the user can tune the mapping by adjusting the search radius.

The last preparation task concerns computing the kilometre information of the roads, which is especially important for freeways and highways, where no address information exists. For that purpose, the user only has to select one of the registered kilometre points during the survey. If no kilometre point was registered, he can enter a new one and determine its location using the map. If the survey covered the inspection of more than one road, a separate kilometre point has to be set for each road, as each road has its own kilometer mileage.

**Post-processing.** The use of GPS enables a precision of about 15 metres for the positioning of events on the road. This is far better than the estimation of the location with the aid of the kilometre signs at every 500 metres on the road recorded on videotape. However, during the survey it is sometimes hard to register the event at the right moment, where a delay of 1 second can lead to a difference of 25 metres from the actual location of the event. Therefore, the user has been given the possibility to correct the location of the events during post-processing (see Figure 8).

The attributes of each registered event can be edited as well. For our sample Event Type “Motorway” the user can at this point, select a pre-defined shortcoming of a captured event and select a pre-defined countermeasure for the shortcoming. During post-processing it becomes clear how important it is to invest enough time for the definition of the underlying

\(^2\) http://www.teleatlas.com/
data structure, because once done it is going to be used over and over again during post-processing and can save a lot of time.

During post-processing the user has further to set the risk factor of each registered event. It is deliberately not allowed to pre-define the risk factor of an event, as the same event may not induce the same grade of risk everywhere it is observed and often depends on several factors. An unguarded traffic sign on a section with a speed limit of 130 km/h, for instance, is much more dangerous than on a section with a speed limit of 60 km/h. The idea of setting default values that could be changed by the user if necessary, was rejected to prevent cases where the user forgets about it or neglects it, which would affect the safety evaluations of the road.

![Figure 8: User interface for post-processing](image)

**Reporting**

Reports of RSIs are very important as they represent summarisations of the inspections to be presented to several authorities. Because the data is not gathered electronically with traditional methods, the information that has been extracted manually from the collected data is put together in form of written reports. To eliminate several disadvantages of this traditional approach, such as the loss of data or the time that is needed to write the reports and fill out the forms, EVES is equipped with a reporting tool.

Without EVES's reporting tool, the registered data could only be used by EVES itself. The dynamic structure of the event types requires the possibility for the user to define which attributes from which events should be written where in the reports, whether he wants to have screenshots from the video, photographs or map to show the location of an event, etc.

This step has big time-saving potential, as a report can be constructed with a few clicks compared with the traditional manual process of entering each single event, taking screenshots from the video, and marking the events on a map. The constructed report is in the Word format, hence, human readable, but not suited for further processing with the computer.
In order to provide the generation of files that can be further processed, the system has to be able to export its data as well. This is done by generating text files in the so called Comma Separated Values (CSV) format, where each line contains elements of a data record (e.g., attributes of a single event) separated with a defined character, usually a semicolon. Such files are very common and can be processed with standard software like Excel.

6. Conclusions and Future Work

We have seen that road safety inspections are a very good method to gather relevant information about the road and its surrounding regarding the safety of the road. The different implementations in different countries however are very time consuming and expensive, therefore road safety inspections are not implemented as intended.

The comprehensive use of modern computer systems like in the introduced computer aided RSI software “EVES”, the inspection of the complete higher road network of a country becomes feasible. The additional benefit of EVES is that the gathered data is stored electronically and can be further used by other systems like for road evaluating and scoring or for administrative tasks.

Some field tests have shown, that the possible cost savings are sufficient for a full implementation of RSI on the 38.000 kilometres of higher road network in Austria. A pilot project on an area containing about 5.000 kilometres of the higher road network should be performed. Further work groups with authorities from different EU-Countries should be established in order to encourage a consistent EU wide implementation of road safety inspections.

7. References


Development of a new driver behavior model through a novel object detection technique

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Abstract
In this paper a comprehensive framework is proposed to model driver behavior considering the surrounding vehicles. With the proposed structure, the driver consideration and action spaces can be measured and related. Furthermore, a platform is developed and presented which could facilitate a dynamic real traffic data collection to study driver behavior. The application of the developed platform to collect associated traffic data in a follow the leader experiment is presented in which the real microscopic traffic data (e.g. vehicles speed, acceleration, relative distance and speeds to surrounding vehicles) is measured through a unique moving object detection technique. Different schemes of filtering and smoothing are applied to the collected data. A comparison among various car-following models is used to analyze the predicting ability of the models. Two linear models as well as the GM model are used to observe the car-following behavior. The developed platform provides promising capabilities in capturing driving behavior in complex driving conditions using its advanced features and unique moving object detection software. The potential applications of the proposed driving framework and developed platform in the context of collision prevention and driving assistance systems are also discussed.
INTRODUCTION
The recent push for Vehicle-Infrastructure Integration and Cooperation (VIIC) program under Intelligent Transport Systems (ITS), the enhanced knowledge of driver behavior will contribute to the task of preparing for the role of the driver in new driving environment and addressing a number of new issues. They include the changing roles, responsibilities, skills, and knowledge needs for driving a vehicle that is partially automated, senses the environment via wireless communications, and performs cooperatively to reduce crash risk and enhance safety. Depending on the level of ITS deployment, the degree of technology uptake, user preferences and acceptance, human drivers within current ITS driving environments may no longer considered the only intelligent subsystem in the ITS environment. Vehicles, road infrastructure and traffic management centers are being equipped with the ability to sense, perceive, evaluate, make decisions and take control.

The objective for developing new driver behavior model is to uncover the interactive nature between input factors and behavioral responses. The main challenge is how to utilize the available technological solutions for a right level of the complexity of interactions. Figure 1 presents an outline of a proposed framework [1]. This framework considers explicitly two types of interaction taking place in the driving context: those between drivers and road traffic environments and those between drivers and vehicles. These two types of interaction can also reflect two important physical activities in driving: sensing and control. The sensing is supported by in-vehicle sensing. The Driver Behavior Modeling Agent will be located in between driver and vehicle to capturing the traffic and the vehicle control performed by the driver. This agent will receive the sensed data of traffic and driver from the in-vehicle sensing device. Understanding the deriver behavior is therefore the core issue in the proposed model.

![Figure 1: A framework for measuring and modeling driver behavior [1].](image)

Within this context, it is obvious to see that a core research that improves our understanding of the driver behavior in this driving environment is valuable and crucial. It is for this reason that this part of the
research is dedicated to the development of a platform to understand the driver behavior (and specifically the car-following and lane changing behaviors) using real traffic data. With this in mind, the objective of this paper is twofold. First, a framework is proposed to model driver behavior considering surrounding vehicles. With the proposed structure, the driver consideration and action spaces can be measured and related. Second, a platform is developed and presented which could facilitate a dynamic real traffic data collection to study driver behavior.

**MODEL FOR REPRESENTING LOCAL TRAFFIC AND DRIVER’S RESPONSE**

Figure 2 describes the model’s structure for representing local traffic situation and driver’s responses. In this figure, local traffic surrounding current vehicle is represented by a polygon which connects the corner of current vehicle with other surrounding vehicles in a multi-lane road setting. With this proposed structure, the driver consideration and action spaces can be measured and related. The core information in the driver consideration space is the four dynamic data sets. They measure the dynamic interaction between current vehicle and the surrounding traffic environment in terms of distance, time, vehicle size and speed differences between current vehicle and the surrounding traffic. They provide a rich set of information perceived by driver under his/her consideration space together with lane keeping and situation awareness. If these four data sets can be captured dynamically and accurately, they will provide valuable information on the dynamic interaction between driver and surrounding traffic. An important characteristic of the proposed model compared to the traditional car-following and lane changing models is that it facilitates both behaviors in an integrated and coherent framework. This can significantly enhance the capability of the proposed model to safety applications such as rear end and side conflicts prevention warning systems (due to lane changing). This requirement is conditioned on the availability of current technology in data collection which will be the focus of the next section. In the remaining sections of this paper, the developed platform which is capable of collecting the object vehicle surrounding traffic data, proposed in this study, is explained. The application of the developed platform to collect required data in a basic follow the leader experiments is presented to show the capability of the developed platform.

![Figure 2: Polygon-based model for representing local traffic situation.](image-url)
EXPERIMENT
In order to provide the data of the driver's behavior in real traffic, an instrumented vehicle that uses different measuring device is needed. The instrumented vehicle is used to measure the velocity and acceleration of the surrounding vehicles and its relative distance to surrounding vehicles. A program to process the measured data is needed to interface with the sensory equipment and also to give outputs with which the measured data can be interpreted.

Equipment
Instrumented vehicle
The vehicle used for the experiment is a Subaru 2005 pick-up that is equipped with two Laser devices to measure the front and rear car's distance to the surrounding vehicles and a GPS to measure the speed and timing of the instrumented car (see Figure 2). The specification of the laser, the GPS and the description of the software developed are given in the following sections.

Laser measuring sensor
The laser device used is the Sick Laser Measuring Sensor (LMS291). The Sick Laser Measuring Sensor is an extremely accurate distance measurement sensor that can interface with computer via RS232 or RS422. The laser can transmits beams in a complete 180° direction making it easy and suitable for detecting the neighboring cars. Mounting two lasers (one on the front bumper and one on the back bumper) would facilitate the collection of surrounding vehicles traffic data in a perfect 360 degree.
Laser transmits the data (headway) through serial interface RS422. A serial to USB converter is used to connect and transmit data to computer’s USB port with sampling rate of 37 HZ. The maximum distance taken from laser is 81 meters. 180 degrees is scanned with increments of 0.5 degrees. The laser sends data packet starting with a defined header. The header varies with the laser settings. The packet header must be checked to ensure the correct packet including proper data is received. This is done using Visual C++.

GPS and cameras
The GPS utilized is made by the Trimble’s company and it has two parts: the base and the antenna. The GPS has the accuracy of 0.1 Km/hr. GPS is connected through RS232 to USB converter to PC. GPS sends NMEA sentences i.e. $GPGGA and $GPRMC with frequency of 10 Hertz. Accuracy of GPS is determined using $GPGGA this sentence contains number of Satellites and Horizontal Dilution of Precision (HDOP). In order to achieve an accurate data from GPS, the data with equal and more than 5 observed satellites and a Relative accuracy of horizontal position of less than 4.4 is recorded with the software. Speed over ground in knots was extracted from $GPRMC sentences. $GPGGA and $GPRMC is also contains Latitude and Longitude. Additionally, there are also two cameras to capture the events in the front and rear of the vehicle.

LDVTS platform
Although every one of the equipment used in the project is supplied with its own software, but the need for a powerful and coherent platform that would integrate the output of the sensory devices and interpret the results in a meaningful manner is essential. In this study, Laser-based Dynamic Vehicle Tracking System (LDVTS) software, which integrates the output of the sensing devices and analyses and interprets the results in a meaningful manner, is developed using VC++ Open GL library. The software processes the data from the lasers, GPS and the video cameras to output information that includes the objects that are detected by lasers, the speed of the vehicle and recorded video of the events. One of the important features of the LDVTS is its unique moving object recognition capability. With this feature embedded in the software, it makes it possible to capture moving objects while scanning the environment in front of and at the rear of the instrumented vehicle. It also produces graphs of the headway, speed and acceleration of the...
vehicle over time. It uses a sophisticated filter routine to eliminate noise from the data. The software has been developed to configure the laser setting, synchronize the Lasers and GPS, identify moving objects, and plot the data in real time/playback, and supports data export in a range of standard formats. The headway, speed and acceleration data are imported into the Matlab software system for filtering, smoothing, interpolation, and plotting. A snap shot of the data playback function available in LDVTS is shown in Figure 3.

LDVTS and lasers could provide vital inputs to driver or potential driving assisting systems from which the system could suggest the safest way of driving. For example, if the vehicle in front reduces its speed, LDVTS utilizing lasers would recognize this event and the driving assistance system would then consider the surrounding traffic conditions (through the other information provided by the lasers) to explore the safest way of driving in this situation. This could be by maintaining the same speed but lane changing to avoid the vehicle in front (therefore, avoiding sudden deceleration and potential rear end crash) or if lane changing is not possible, to reduce the speed while traveling in the same lane.

![Figure 3: A snap shot of the data playback function from LDVTS.](image)

### Procedure

Two sets of different experiments are conducted in this work to show the capability of LDVTS in the context of the proposed driving behavior framework. One set of experiments is done in a controlled condition where the follower (instrumented car) tries to maintain its distance the same from the leading car where is traveling with a pre defined speed profile. The other set of experiments is performed in real traffic with no control on the leading car’s behavior. The latter is performed to validate the data obtained from the lasers and the GPS device and to confirm the offline calculation of the front car parameters (Distance traveled and speed) beside of validating the car-following models. First set of experiments includes six
experiments and the second set of data consists of two different experiments. These experiments are done either in Monash or Eastern Freeway of the city of Melbourne, Australia.

**Controlled speed experiments**
The instrumented vehicle (the following car) is driven behind a car in Eastern Freeway, Melbourne, in the direction of East to West where its speed limit is 100 Km/hr. The speed profile of the controlled car (the leader) is a step function where follower tries to match in order to maintain its distance with the leader.

**Real traffic experiments**
The instrumented vehicle follows the front vehicle (leader) in Monash Freeway in the city of Melbourne, Australia. A safe distance is tried to be kept at all the time with the front car. In all of the experiments, the drivers of the front car in the traffic are unaware of the experiment. The driver of the following car is instructed to keep its distance the same to the front car at all time during the experiments (the distance to the leading car varies from one experiment to the other one). More than ten different experiments are conducted for each set of experiment, that due to various reasons like for example, the interference of other cars in the traffic with the experiment, noisy signal of the output of the laser or GPS, etc…, only 6 of the better runs are used for analysis for each of the set of the experiments conducted.

**Processing the Experiment’s Results**

**Filtering**
The collected car-following data shows noisy pattern and therefore, a filtering system is needed to estimate the state of the system from noisy sensor information state. In order to extract the data from the noisy data produced from different sensors (laser and the GPS), some kind of state estimator (filtering system) is needed. Two types of filtering are applied to the data. The first type of filtering is done based on the realistic rate of change of the headway distance and the follower speed. The out of range noisy data which are easily distinguishable are also cancelled with this type of filtering. The second type of filtering is carried out through Kalman filtering algorithm to smooth the data. The Kalman Filter toolbox in Matlab is used to smooth the data. The Kalman smoother implements the RTS equations. The Rauch-Tung-Striebel (RTS) algorithm performs fixed-interval offline smoothing.

**Leader car’s parameters**
In all of the experiment performed, the instrumented vehicle is used as the following car, measuring the headway distance and the speed of the following car. There are no direct measurements of the leading car’s traveled distance and speed. The calculation of these parameters is done offline and based on the information of the following car’s speed, the headway distance and time as following.

The distance traveled by the vehicle B (the leading vehicle) is given by equation 1:

$$X_B = X_A + \text{Headway}$$

Where:

- \(X_B\) = \(X_A^{2} + \Delta X_A\) and
- \(\Delta X_A = \frac{1}{2} (t_2 - t_1)(V_1 + V_2)\)

\(V_1\) and \(V_2\) and \(t_1\) and \(t_2\) are velocity and time for which vehicle A (the following vehicle) has traveled during time \(t_1\) and \(t_2\)

\(X_A\) = Distance traveled by the Vehicle A.

\(X_A^{2}\) = distance traveled by A in the previous increment (equal to 0 at time 0)
The speed of vehicle B is then the derivative of the distance traveled by it. A technique for differentiating a noisy signal is developed based on applying a least squares linear regression model to consecutive points defined by the equation of:

\[ X = mt \tag{2} \]

Where \( m \) is the slope or rate of change of the line that represents the first derivative of equation 2. An equation for the best fit-line defining these points where \( m \), or slope of the line represents the average rate of change of the line over the range of the values of \( X \). Extending this reasoning one step further, if the number of points \( n \) over which the regression line is calculated is varied, the degree of smoothing that is applied to the calculated rate of change can be adjusted. The higher value of \( n \) gives greater smoothing of the derivative of \( X \). The following explains graphically how the regression model is applied to the data points represented by \( X \):

\[ m_i = \frac{n \sum x_i x_i - (\sum x_i)^2 \sum x_i^2}{n \sum x_i^2 - (\sum x_i)^2 \sum x_i^2} \tag{3} \]

Where:

- \( m_i \) = the slope of the line segment
- \( n \) = the smoothing factor
- \( t_i \) = the sampled position in time
- \( X_i \) = The sampled value

And

\[ X_i \quad X_{i+1} \quad X_{i+2} \quad X_{i+3} \quad X_{i+4} \quad X_{i+5} \]

\[ m_i \quad m_{i+1} \quad m_{i+2} \quad m_{i+3} \quad m_{i+4} \\]

Line Segment 1

Line Segment 2

Line Segment 3

Line Segment 4

Note that a smoothing of 3 is used in the above and an overlap exists in the line segment calculations which yields the same number of points in the differentiated data as existed in the data represented by \( X \). The same type of calculation is used for calculating the follower’s acceleration from the velocity profile that is recorded by the GPS.

**Car-Following Models**

Acceleration model first was developed in 1950s to model the acceleration that drivers apply throughout driving. It is classified as car-following and free flow conditions. Car following applies when the subject vehicle is following a vehicle in front hence the acceleration is a reaction to attributes of the leader. There are different car-following models developed in the literature. The models date back to 1950’s [2] where the first models are developed. In this research three different models are adopted for use with the real traffic. The purpose is to apply real traffic data to the car-following models to evaluate the results. In the following section the description of the models are given.

**Linear Model**

Chandler at al. [3] developed a linear model in General Motors research labs which is given as:

\[ a_H(t) = \alpha \Delta V_{fr \mid r} \left( t - \tau_H \right) \tag{4} \]

Where
\( a_n(t) \) = acceleration applied by the driver \( n \) at time \( t \\
\alpha = \text{Constant} \\
\Delta v_n(t_1) = \frac{1}{2} a_n(t_1 - \tau_n) \\
\dot{v}_n(t_1) = \text{leader or front vehicle speed at time} (t_1 - \tau_n) \\
v_n(t_1) = \text{subject speed at time} (t_1 - \tau_n) \\
t = \text{time of observation} \\
\tau_n = \text{reaction time for driver} n \\

The constant term is estimated using the correlation analysis method and real traffic car-following data.

**General Motors 2 parameter (GM2P) Model**

The linear model has a constant sensitivity term which was further developed by Gazis et al. in 1961 [4] to accommodate the macroscopic speed density relationship. The space headway is incorporated in the model. Hence the main two constraints are safe headway and desired speed. The model is defined as:

\[
a_n(t) = \frac{\Delta v_n(t_1)}{\omega_{n|t_1} \Delta t_n} \Delta v_{n|t_1} (t_1 - \tau_n)
\]

(5)

Where \( \Delta v_{n|t_1} (t_1 - \tau_n) \) is the space headway at time \( (t_1 - \tau_n) \).

The parameter \( \alpha \) is estimated for each data set using correlation analysis.

**General Motors 3 parameter (GM3P) Model**

Since the equation 4 does not yield the free-flow speed at zero density, the following equation addresses this problem and is developed by Edie [5]:

\[
a_n(t) = \alpha \frac{\Delta v_n(t_1)}{\omega_{n|t_1} \Delta t_n} \Delta v_{n|t_1} (t_1 - \tau_n)
\]

(6)

**RESULTS**

The speed profile of the controlled car (the leader) in the controlled speed experiments is a step function where the speed starts at 60 Km/hr or 70 Km/hr and is maintained for a period of approximately 60 seconds. The speed is then raised by either 10 or 20 Km/hr in a short period of time of approximately 15 to 25 seconds. There could be one or two steps on each run. Some of the experiments include the part that the speed is reduced in the step manner and some do not.

To show the process and the efficiency of the filtering process, the raw data for the headway distance and the follower speed obtained from the experiment for one of the controlled speed experiments is shown in Figure 4a. The results of applying the first type of filtering and the Kalman filtering are shown in Figure 4b. As it can be seen the results produced are of satisfactory condition and present the true state of the system. This can be verified on the controlled speed test where the speed and the headway are kept at the known values of 10 m (average value) for the headway and the speed of 70 Km/hr and 80 Km/hr. These are the controlled values that are maintained during the experiments.
Figure 4: The headway distance and the follower speed for a controlled speed test without any filtering (a) and after complete filtering (b).

In order to calculate the distance traveled by the front vehicle, equation 1 is applied to the filtered and smoothed data obtained for the headway distance and the follower's velocity measured for all the experiments. equation 2 is then used to calculate the leader's velocity and follower's acceleration. The results of only one of the experiments (one from each set of experiments) are presented in Figure 5. In all of the experiments the driver of the following car tries to keep a constant distance from the leader. This is indicated by an almost constant headway distance and constant and zero velocity and acceleration profiles in all the experiments.
Figure 5: Headway distance (a), the follower and leader’s speed (b) and the follower’s acceleration (c) for the controlled speed.
Figure 6 shows the process of calculating the reaction time of the driver based on the follower’s speed and the leader’s speed pattern and the work done in [6]. Although a specific experiment for determination of the reaction time is not conducted, but the data of the controlled experiment (Figure 5) is used for calculation of the reaction time. The data is valid for this purpose since the follower driver was instructed to follow the leader in the quickest time possible in order to maintain his distance from the leader. A portion of Figures 5b and 5c (along with acceleration of the leader) is enlarged in Figure 6a and 6b. As the leader is changing its speed (the red line), the follower tries to match the speed by accelerating or decelerating which causes the follower’s speed to increase or decrease. At the locations A and B indicated in the figure, the reaction time is measured to be 1.75 and 1.5 seconds. Similar procedure is done for all the experiments and the average reaction time is calculated to be approximately 1.5 seconds. It has to be noted that for every experiment, one must identify the region of the interest where points like shown in Figure 6 can be identified. This is done for all the experiments to obtain an average reaction time. All the experiments are done with the same follower and leader driver and therefore the reaction time is expected to be close values in each of the experiments.

![Figure 6: Calculation of the reaction time using the Follower and Leader Speed (a) and acceleration (b) Pattern.](image-url)
To find the parameter of the car-following models which their equations are given by equations 4 to 6, the acceleration along with the corresponding headway and speed are used in a nonlinear regression analysis. The values of the parameters are obtained using the Data fit software and are shown in Table 1. The values of the parameter $\alpha$ for all the experiments for the three models are closely related to each and average value may be calculated and be used as the final value for each model.

Table 1: the constant parameters of the car-following.

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<tr>
<th>Run No.</th>
<th>Linear $\alpha$</th>
<th>GM 2P $\alpha$</th>
<th>GM 3P $\alpha$</th>
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<td>1.4831</td>
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<td>Average</td>
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</tbody>
</table>

CONCLUSIONS

In this study a framework is proposed to model driver behavior considering surrounding vehicles. With the proposed structure, the driver consideration and action spaces could be measured and related. An important characteristic of the proposed driving model compared to the traditional car-following and lane changing models is that it facilitates both behaviors in an integrated and coherent framework. This can significantly enhance the capability of the proposed model to safety applications such as rear end and side conflicts prevention warning systems (due to lane changing).

Additionally, a platform is developed and presented which could facilitate a dynamic real traffic data collection to study driver behavior in complex driving conditions. As part of this platform Laser-based Dynamic Vehicle Tracking System (LDVTS) software is developed using VC++ Open GL library. The software processes the data from the lasers, GPS and the video cameras to output information that includes the objects that are detected by lasers, the speed of the vehicle and recorded video of the events. One of the important features of the LDVTS is its unique moving object recognition capability. With this feature embedded in the software, it makes it possible to capture moving objects while scanning the environment in front of and at the rear of the instrumented vehicle.

To demonstrate the capability of the developed platform, it is utilized to collect associated traffic data in a basic follow the leader experiment in which the real microscopic traffic data (e.g. vehicles speed, acceleration, relative distance and speeds to vehicles in front) is measured and used to study the car-following behavior.

In that, the data obtained from twelve different sets of real traffic data are collected and used for evaluation and comparison of three different car-following models. Different techniques of smoothing of data are applied in order to smooth the noisy data. The parameter of the three models may be averaged and used as a single value for all the experiments.

The developed platform provided promising capabilities in capturing driving behavior in complex driving conditions using its advanced features and unique moving object detection software. Utilizing the developed platform to study the impact of the surrounding vehicles on the driving behavior of the subject vehicle, particularly the follower of the subject vehicle is a promising future direction for this research.
REFERENCES


ABSTRACT

Traffic safety analysis has often been undertaken using historical collision data. However, there are well-recognized availability and quality problems associated with collision data. In addition, the use of collision records for safety analysis is reactive: a significant number of collisions has to be recorded before action is taken. Therefore, the observation of traffic conflicts has been advocated as a complementary approach to analyze traffic safety. However, incomplete conceptualization, and the cost of training observers and collecting conflict data have been factors inhibiting extensive application of the technique. Therefore, the successful automation of extracting conflicts from video sensors data using computer vision techniques can have practical benefits for traffic safety analysis. This paper describes a comprehensive system for automated road safety analysis using video sensors. The system automatically detects traffic conflicts in video data and calculates several conflict indicators. The paper describes two applications of the automated system. The first deals with detecting pedestrian/vehicle conflicts in downtown Vancouver. The second application introduces a probabilistic framework for the analysis of road user interactions. The framework provides computational definitions of the probability of collision for road users involved in interactions.

1 INTRODUCTION

The importance of reducing the social and economic costs associated with road collisions cannot be overestimated. The global number of road collision fatalities was approximately 1.3 million in 2004 with road collisions are predicted to be the 8th most common cause of death by 2030 (Mathers and Loncar, 2005). Traffic safety analysis has been traditionally undertaken using historical collision data. However, there are well-recognized problems of availability and quality associated with collision data. In many jurisdictions, the quantity and quality of collision data has been degrading for several years. Additionally, the use of collision records for safety analysis is a reactive approach: a significant number of collisions has to be recorded before action is taken (Sayed and Zein, 1999). Because of these problems, the observation of traffic conflicts has been advocated as an alternative or complementary approach to analyze
traffic safety from a broader perspective than collision statistics alone (Perkins and Harris, 1967; Amundson and Hyden, 1977; Hyden, 1987). A conflict is defined as “an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged” (Amundson and Hyden, 1977). The Traffic Conflict Technique involves observing and evaluating the frequency and severity of traffic conflicts by a team of trained observers. Traffic conflicts are more frequent than collisions, and their study can give detailed information about safety. The technique therefore provides a means for the analysts to immediately observe and evaluate unsafe driving maneuvers at an intersection. However, incomplete conceptualization and the cost of training observers and collecting conflict data have been factors inhibiting extensive application of the technique. Therefore, the successful automation of extracting conflicts from video sensors data using computer vision techniques appears to have practical benefits for traffic safety analysis. Some of the most promising approaches rely on video sensors and intelligent techniques to interpret video data, including computer vision and machine learning. Vision-based systems for traffic monitoring would reduce the workload of human operators and help improve our understanding of traffic behavior. Video sensors for traffic monitoring have a number of advantages, among which are the ease of installation, the possibility to get rich traffic description, and the scope of the areas covered by a camera.

This research describes a complete system to interpret vehicle interactions and detect traffic conflicts in real world video data. As well, the paper describes two applications of the automated system. The first deals with detecting pedestrian/vehicle conflicts in downtown Vancouver. The second application introduces a probabilistic framework for the analysis of road user interactions. The framework provides computational definitions of the probability of collision for road users involved in interactions.

2 A VISION-BASED SYSTEM FOR AUTOMATED ROAD SAFETY ANALYSIS

Despite the potential benefits of automated traffic safety analysis based on video sensors, limited computer vision research has been directly applied to road safety (Kamijo et al., 2000; Atev et al., 2005; Laureshyn and Ard’o, 2006) and even less so to the detection of traffic conflicts. Maurin et al. (2005) state that “despite significant advances in traffic sensors and algorithms, modern monitoring systems cannot effectively handle busy intersections”. Such a system requires a high level understanding of the scene and is traditionally composed of two levels of modules (see Figure 1): 1) a video processing module for road user detection and tracking, and 2) interpretation modules for traffic conflict detection.

For road safety applications, our approach relies on the building of two databases: a trajectory database, where the results of the video processing module are stored, and an interaction database, where all interactions between road users within a given distance are considered, and for which various indicators, including collision probability and other severity indicators, are automatically computed. Identifying traffic conflicts and measuring other traffic parameters becomes the problem of mining these databases.

The road user detection and tracking module used in the system described in this paper relies on a feature-based tracking method that extends to intersections the method described in Beymer et al. (1997). Feature-based tracking is preferred because it can handle partial occlusion. The tracking of features is done through the well known Kanade-Lucas-Tomasi feature tracker. Stationary features and features with unrealistic motion are filtered out, and new features are generated to track objects entering the field of view. Since a moving object can have multiple features, the next step is to group the features, i.e. deciding what set of features belongs to the same object, using cues like spatial proximity and common motion. A graph connecting features is constructed over time. Two parameters are crucial for the success of
the method: the connection distance $D_{\text{connection}}$, i.e. the maximum distance between two features for their connection, and the segmentation distance $D_{\text{segmentation}}$, i.e. the maximum difference between the minimum and maximum distance between two features. A detailed description of the tracking algorithm is presented in Saunier and Sayed (2006). The tracking accuracy for motor vehicles has been measured between 84.7% and 94.4% on three different sets of sequences. This means that most trajectories are detected by the system, although overgrouping and oversegmentation still happens and may create some problems.

![Image](image.png)

Figure 1: Overview of a modular system for vision-based automated road safety analysis

3 THE AUTOMATED SYSTEM APPLICATIONS
3.1 Detecting Pedestrian/Vehicle Conflicts in Downtown Vancouver
This application presents the use of the previously mentioned automated video analysis system to: 1) detect and track road users in a traffic scene, and classify them as pedestrian and motorized road users; 2) identify important events that may lead to collisions; 3) calculate several severity conflict indicators. The system seeks to classify important events and conflicts automatically, but can also be used to summarize large amounts of data that can be further reviewed by safety experts. Difficulties occur in scenes where the traffic is mixed and the road users have very different sizes, e.g. vehicles and pedestrians, and the connection and segmentation distances can only be adjusted for one type of road user. To address this issue, the original system has been extended by identifying the types of the road users. The parameters are adjusted for pedestrians, and consequently the motorized vehicles are over-segmented. Once the groups of features belonging to motorized vehicles are identified, the feature are processed a second time by the grouping algorithm using larger connection and segmentation distances. In the current system, a simple test using a threshold on the maximum speed of each road user is sufficient to discriminate between pedestrians and motorized road users in most cases.

A video dataset collected over two days at an intersection in Downtown Vancouver, British Columbia is used for demonstration. The main interacting movements are pedestrian crossing and left-turn vehicles. Left-turn traffic at signalized intersections poses a particularly
increased risk of collision for pedestrians. Furthermore, this intersection is unique in that it is a skewed intersection within a corridor grid of streets all containing right-angle intersections. Hence, there is a high possibility of observing an adequate number of important interactions between pedestrians and motorists that involve a risk of collision. In this study, important events occurred when a pedestrian and a vehicle co-existed inside the monitored crosswalk. Video recording was conducted for a total of 20 hours over two business days. Approximately, a total of 7000 left-turning vehicles and 2100 pedestrians were observed. These volume estimates are derived from the automated video analysis.

The system detects all events constituted by the pairs of pedestrians and vehicles that are in the traffic scene simultaneously. Four conflict indicators were calculated in this application. One of the most widely used conflict indicators is Time-to-Collision (TTC). TTC is defined as “…the time that remains until a collision between two vehicles would have occurred if the collision course and speed difference are maintained.” Other conflict indicators are used to capture different proximity aspects. Post-Encroachment Time (PET) is the time difference between the moment an offending road user leaves an area of potential collision and the moment of arrival of a conflicted road user possessing the right of way. Gap time (GT) is a variation on PET that is calculated at each instant by projecting the movement of the interacting road users in space and time (Archer, 2004). Deceleration-to-Safety Time (DST) is defined as the necessary deceleration to reach a non-negative PET value if the movements of the conflicting road users remain unchanged (Archer, 2004).

Validation of the system was carried out by comparing system results with a sample of events manually classified by a human observer, using the definition of important events given in the US FHWA observer’s guide (Allen et al., 1978). A combination of the four conflict indicators could enable the system to automatically capture 89.5% of the conflicts. Combining information from four conflict indicators proved successful in reporting the majority of conflicts identified by a human observer. Figure 2 shows sample frames of important events automatically detected by the system. More results are reported in Ismail et al. (2009).

Figure 2: sample of automatically detected important events with the road users’ trajectories. The numbers under each image are respectively the min TTC (seconds), PET (seconds), maximum DST (m/s2), and min GT (s). in the images, the road user speed is indicated in m/s.
3.2 A Probabilistic Framework for the Automated Analysis of the Exposure to Road Collision

This application presents a comprehensive probabilistic framework for automated road safety analysis. Building upon traffic conflict techniques and the concept of the safety hierarchy, it provides computational definitions of the probability of collision for road users involved in an interaction. It proposes new definitions for individual road users and aggregated measures over time. This allows the interpretation of traffic from a safety perspective, studying all interactions and their relationship to safety.

The formulas presented in this application are based on Hu et al. (2004). The collision probability for a given interaction between two road users can be computed at a given instant by summing the collision probability over all possible motions that lead to a collision, given the road users’ states. This requires the ability to generate for each road user at any instant a distribution over its possible future positions given its previous positions. A possible future motion, i.e. a temporal series of predicted positions, defines an extrapolation hypothesis. The collision probability computation is approximated by a discrete sum when taking into account a finite number of the most probable extrapolation hypotheses.

First the collision probability at time \( t_0 \) for two road users \( A_1 \) and \( A_2 \) with respective observed trajectories \( Q_{1,t,t_0} \) and \( Q_{2,t,t_0} \) (before \( t_0 \)) is defined when considering only one extrapolation hypothesis for each, respectively \( H_i \) and \( H_j \). The predicted positions according to the hypotheses \( H_i \) and \( H_j \) are computed for a number of time steps: the predicted time of the collision \( t_{i,j} \) is the first instant at which the road users would be in contact. The larger \( \Delta_{i,j} = t_{i,j} - t_0 \), the more likely the road users can react and avoid the collision. This time takes into account speed and distance and is directly measurable against the road users’ reaction times. The formula of the probability of collision given hypotheses \( H_i \) and \( H_j \) is taken from Hu et al. (2004):

\[
P(\text{Collision}(A_1, A_2) | H_i, H_j) = e^{-\frac{\Delta_{i,j}}{2\sigma^2}} \tag{1}
\]

where \( \sigma \) is a normalizing constant. It is estimated in (22) that this probability should change when the elapsed time \( \Delta_{i,j} \) is close to the road user reaction time. Therefore \( \sigma \) is chosen to be equal to an average user reaction time*. The number of predicted positions can be limited to \( 3\sigma \), as the resulting probability is very close to zero when \( \Delta_{i,j} \) reaches that value.

The collision probability for two road users \( A_1 \) and \( A_2 \) at \( t_0 \) is

\[
P(\text{Collision}(A_1, A_2) | Q_{1,t,t_0}, Q_{2,t,t_0}) = \sum_{i,j} P(H_i | Q_{1,t,t_0}) P(H_j | Q_{2,t,t_0}) e^{-\frac{\Delta_{i,j}}{2\sigma^2}} \tag{2}
\]

where \( P(H_i | Q_{1,t,t_0}) \) is the probability of road user \( A_i \) to move according to extrapolation hypothesis \( H_i \) (same for \( A_2 \) and \( H_j \)). The sum is done over a variety of extrapolation hypotheses, although this number must be limited to maintain reasonable computation times. This formula is illustrated in a simplified example in Figure 3. In a traditional TCT, one could choose a threshold on the collision probability and other indicators to define traffic conflicts. In this approach, road safety can be automatically analyzed in detail by computing continuously the collision probability of all interactions.

When considering the collision probability for only one road user, the formulas have to be adapted. It is not possible to directly sum the collision probabilities of the interactions in which the road user is involved, as only one collision can happen for each extrapolation hypothesis. The predicted positions according to hypothesis \( H_i \) and all hypotheses that the other interacting road user may follow are computed for a number of time steps. If the road

*A value of 1.5 seconds is chosen for the experiments described in this paper.
user follows the motion hypothesis $H_i$, the predicted time of the collision $t_i$ is the first instant at which the road user following motion hypothesis $H_i$ would be in contact with another road user ($\Delta_i = t_i - t_0$). Let $Q_{i(i)}$ be the observed trajectory of this road user and $H_{j(i)}$ the hypothesis that leads this road user to a collision. The collision probability of the road user $A_j$ with $n$ other road users at $t_0$ is

$$
P(Collision(A_j) \mid Q_{1,t_0}, Q_{2,t_0}, ..., Q_{n,t_0}) = \sum_{i,j} P(H_i \mid Q_{i,t_0})P(H_{j(i)} \mid Q_{k(i),t_0})e^{-\frac{(t_i-t_0)^2}{2\sigma^2}}$$

(3)

Figure 3: In this simplified situation, two vehicles approach a T intersection at time $t_0$. Only two extrapolation hypotheses are considered for each vehicle. Vehicle 1 is expected to turn left or right, with respective probabilities 0.4 and 0.6. Vehicle 2 is expected to go straight or turn left, with respective probabilities 0.7 and 0.3. There are two potential collision points, that can happen at times $t_1$ and $t_2$. The collision probability at time $t_0$ is computed as

$$
P(Collision) = 0.4 \times 0.7 \times e^{-\frac{(t_1-t_0)^2}{2\sigma^2}} + 0.4 \times 0.3 \times e^{-\frac{(t_2-t_0)^2}{2\sigma^2}}.$$

The previous definitions deal only with one road user or one interaction between two road users at a given instant. The collision probability for two road users in interaction can be used for the detection of traffic events relevant to safety. However, to characterize a given period of time at a location, one needs a method to accumulate the indicators over all interactions that occurred in the monitored area during this period of time, or over all road users that went through the monitored area during this period of time.

The first aggregation level is the interaction or the road user. This indicator should reflect the highest collision probability over time, but also the amount of time during which this collision probability was high. This should therefore be similar to an integral of the instantaneous collision probability over time. However, issues arise when dealing with real data, e.g. collected after automated road user tracking using video sensors: tracking errors and noise produce measures of collision probability over time which may be randomly truncated and noisy. Hu et al. (2004) report similar observations. This would make it difficult to compare fairly the interactions. Consequently, to improve robustness, it is preferred to use the average of a small number of largest values taken by the collision probability over time. Let $n$ be that number. Let SeverityIndex($A_1, A_2$) and SeverityIndex($A_1$) be the averages of the $n$ largest values taken respectively by the collision probability $P(Collision(A_1, A_2) \mid Q_{1,t_0}, Q_{2,t_0}, ..., Q_{n,t_0})$ over the time that the two road users $A_1$ and $A_2$ interacted in the monitored area, and by the collision probability $P(Collision(A_1) \mid Q_{1,t_0}, Q_{2,t_0}, ..., Q_{n,t_0})$ over the time that the road user $A_1$ has spent in the
monitored area. The values can subsequently be summed over time for all interactions or road users. The severity indices for the time interval $[t_1, t_2]$ are

\[
    \text{InteractionSeverityIndex}([t_1, t_2]) = \sum_{(i, j) \text{ such that } A_i \text{ and } A_j \text{ are observed in Interaction during } [t_1, t_2]} \text{SeverityIndex}(A_i, A_j)
\]  

\[
    \text{UserSeverityIndex}([t_1, t_2]) = \sum_{i \text{ such that } A_i \text{ is observed during } [t_1, t_2]} \text{SeverityIndex}(A_i)
\]

Three sets of data are used. The first is a set of traffic sequences on the same location initially used for the training of traffic conflict observers in the 1980s. Their length ranges from 10 seconds to 60 seconds. This “Conflict” set contains 2941 feature trajectories of a minimum length of 40 frames, and 327 road user trajectories. The second dataset is composed of two long sequences, each close to one hour long, recorded at an intersection in the Twin Cities (United States), in Minnesota. This “Minnesota” set contains 88255 feature tracks of a minimum length of 40 frames, and 11734 road user trajectories. The third dataset is composed of 6 sequences, each about 20 minutes long, recorded in Reggio di Calabria (south Italy). This “Italy” dataset contains 138009 feature tracks of a minimum length of 40 frames, and 9849 road user trajectories.

First the motion patterns are learnt from the feature trajectories, which are smoothed using a Kalman filter beforehand. It is difficult to evaluate such an unsupervised task. The learnt prototypes for the datasets are presented in Figure 4. The visual examination of the motion patterns suggests a plausible division of the trajectory space. Traffic patterns are well identified, and the traffic volumes are consistent with observation.

Since only a few traffic conflict instances are available in the Conflict dataset, only preliminary results obtained for the three detectable traffic conflict instances are reported in this paper (these three traffic conflict instances belong to three sequences of the Conflict dataset). It appears that the prototype trajectories are well suited for the computation of the collision probability. An example of movement prediction is presented for one conflict in Figure 5.

The curves of the collision probability as a function of time, computed using formula 2, are displayed for the three traffic conflicts in Figure 6. For each of these instances, one vehicle is over-segmented, resulting in two trajectories, and thus two traffic events (and two curves). It appears that the collision probability shows an expected evolution over time, starting with low values, increasing until the probability of collision reaches a maximum, to decrease afterward, often truncated due to tracking errors and disrupted trajectories.

Using formula 5, the severity indices of all interactions are computed for the sequences of the Minnesota and Italy datasets, which are both more than one hour long. The distributions of the interaction according to their severity indices are represented individually for each sequence of the two datasets in the Figure 7. As expected, the distributions exhibit the shape of the safety hierarchy, with the frequency of events decreasing as the severity increases. The different sequences in each dataset exhibit different distributions. For example, more interactions for all level of severity are observed in the sequence 2 in the Minnesota dataset. This type of analysis could be performed to compare different situations, for example in before and after studies. It is also possible to study interactions by their locations, by building severity maps, and therefore analyze particular problems in the intersection. More results are presented in Saunier and Sayed (2008).
Figure 4: Motion patterns learnt respectively on sequences of the Conflict dataset (top), the Minnesota dataset (bottom left) and the Italy dataset (bottom right), resulting respectively in 58, 128 and 58 prototype trajectories. The tracks are displayed in color, from white to red indicating the number of matched trajectories in the sequence for each pattern, i.e. the traffic volume along these patterns.

Figure 5: An example of movement prediction in a real traffic conflict situation. The vehicle trajectories are red and blue, with a dot marking their position, and the future positions are respectively cyan and yellow.
Figure 6: Graphs of the collision probability for the three traffic conflicts (collected in three separate sequences), as a function of time (counted in frame numbers). In all sequences, vehicle 1 travels south-bound through the intersection and vehicle 2 comes from an opposing approach. Vehicle 2 turns left in sequence 1 (top) (See Figure 4), right in sequence 2 (middle) and stops in sequence 3 (bottom).
Figure 7: Distribution of the interactions according to their severity indices (with a zoom on the higher severities), quantified by 0.1 (the point at severity index $x$ stands for the number of interactions with severity index between $x-0.1$ and $x$), for the sequences of the Minnesota dataset (top) and the Italy dataset (bottom).

4 CONCLUSION AND FURTHER RESEARCH

This paper presents an automated road safety analysis system based on traffic conflict detection in video data. The system addresses the main shortcomings of the traffic conflict technique which are the cost of collecting the conflict data, and the subjectivity and reliability of observers. This is a generic and robust low-cost solution in the context of the increasing availability of video data which is prohibitively costly to manually process. The system provides the ability to automatically calculate conflict indicators and report important
interactions to a human observer for further examination of traffic interactions. As well, the system should offer a better understanding of vehicle collision failure mechanism, particularly the collision-avoidance behavior of drivers which should help the diagnosis and remedy of the safety problems. Two applications of the system were presented.

In the first application, the movement paths of pedestrians and transversal trajectories of vehicles were analyzed and a group of conflict indicators were calculated for each pedestrian-vehicle interaction. A combination of four conflict indicators proved useful in the identification of important events and traffic conflicts. The second application presented a comprehensive probabilistic framework for automated road safety analysis. It provided computation definitions of the probability of collisions for road users involved in an interaction. By integrating this framework into a complete system for vision-based road safety analysis, it is shown that these definitions are suitable for an automated system. This provides detailed severity measures, exposure estimates and a method to detect and study traffic conflicts. The system is demonstrated using real traffic data, including some traffic conflict instances, illustrating the approach and its usefulness.

REFERENCES
ABSTRACT
This study aims at investigating the association between crash frequencies and various types of trip productions and attractions in combination with the road characteristics of 1349 Traffic Analysis Zones (TAZs) of four counties in the state of Florida. This paper contributes to the macro level crash modeling research by considering various trip related data into account. Previous studies in zone level safety have not explicitly considered trip data as explanatory covariates. Negative binomial models were developed separately for total crashes, severe crashes (fatal and severe injury crashes), total crashes during peak hours and pedestrian and bicycle related crashes taking various groups of predictors into considerations. It was found that total crash model and peak hour crash model were best estimated by the total trip productions and total trip attractions. Severe crash model was best fit by the trip related variables only and pedestrian and bicycle related crash model was best fit by the road related variables only. This study points to different approaches when predicting crashes at the zonal level.

1 INTRODUCTION
The nature and extent of roadway crashes vary by a wide range depending on roadway types and facility, driver characteristics, land-use pattern and various other factors. A considerable amount of research has been conducted to reduce crash occurrence that tolls millions of lives and immeasurable human sufferings each year throughout the world. Since a crash is associated with a complex interaction of various factors, micro level crash analysis (e.g., road specific crash analysis, crash specific safety analysis, event specific analysis, etc.) can lead toward better insight about the causes of the crash. However, a transportation network is a conglomeration of various sets of road-traffic-environment modules and is featured by multi-categories of inter-dependent factors. This essentially imposes a challenge in the macro/aggregate analyses of crashes. Aggregate level considerations being vitally important in transportation planning have been emphasized in several macro level studies during the past few years. Macro analysis of crash prediction models have been tried at census block groups, traffic analysis zones (TAZs), census tracts, and for counties considering various demographic, socio-economic, road and travel characteristics (e.g., Amoros and Laumon, 2003; Aguero-Valverde and Jovanis, 2006; Noland and Oh, 2004; Noland and Quddus, 2004; Karlaftis and Tarko, 1998; Wier et al., 2009).
The study in this paper was based on 1349 TAZs of four counties in the state of Florida. This study aims to investigate the association between crash frequencies and various types of trip productions and attractions in combination with the road characteristics of the TAZs. The primary objective of this paper is to investigate the impact of different trip productions and attractions in modeling crash frequencies for the TAZs. Previous macro level road safety studies have not explicitly considered trip data as the explanatory covariates. Therefore it is thought that the results of this study add to the literature by examining trip effects on aggregated crash frequency analysis.

The study examined four different response variables which are total crashes, severe (fatal and severe injury) crashes, peak hour crashes and pedestrian and bicycle related crashes per TAZ. Peak periods were estimated based on the temporal variations of the aggregated hourly crash frequencies and their association with different trip and road related covariates were of particular interest. Also, since both state and non-state road characteristics within a TAZ were considered in the study, pedestrian and bicycle related crashes were of special interest as most of these categories of crashes occur in moderate to low speed roadways and streets.

2 LITERATURE REVIEW
Macro level crash prediction models have been investigated at various spatial aggregations. These models have incorporated different categories of variables in predicting crash occurrences. Amoros and Laumon (2003) compared traffic safety in several counties in France taking different road types and socio-economic characteristics into account. Aguero-Valverde and Jovanis (2006) investigated crash risk for Pennsylvania counties with respect to socio-demographics, weather conditions, transportation infrastructure and amount of travel. Noland and Oh (2004) examined association of various road network infrastructure and some demographic and socio-economic variables with crashes in the counties of Illinois. Amoros and Laumon (2003) found significant interaction between county and road type. Other positively associated road related significant factors in the above mentioned studies included road mileage and road density (Aguero-Valverde and Jovanis, 2006) and number of lanes (Noland and Oh, 2004). Among the demographic variables Aguero-Valverde and Jovanis (2006) found that counties with a higher percentage of the population under poverty level, higher percentage of their population in age groups 0-14, 15-24, and over 64 have significantly increased crash risk. Noland and Oh (2004) commented that their analyses results did not change much when demographic variables were included, although they found these variables appear to capture the residual time trend associated with reductions in both fatalities and reported crashes.

The crash prediction studies at county level have been thought to suffer from the problem of spatial heterogeneity. Karlaftis and Tarko (1998) utilized a stratification scheme to solve this problem to some extent. They used clustering techniques to generate homogeneous groups with similar socio-economic, traffic and infrastructure characteristics for the counties of Indiana. Their results indicated that models developed for homogeneous clusters of counties were efficient than the joint models.

Wier et al. (2009) looked at the vehicle-pedestrian injury collisions at 176 San Francisco, California census tracts which are spatially disaggregated from the counties. The predictor variables examined in their study included street, land use, and population characteristics and their final model was able to explain approximately 72% of the systematic variation of the vehicle-pedestrian injury collisions at the census tract level. It was evident from their study that traffic volume was the primary cause of vehicle-pedestrian injury collisions at the area level. Additionally, employee and resident populations, arterial streets without public transit, proportion of people living in poverty, and proportion of people aged 65 and over were among the other statistically significant predictors.
Noland and Quddus (2004) analyzed ward level crash data for England using land use types, road characteristics and demographic data. Their (Noland and Quddus, 2004) findings suggested that areas with high employment density had more traffic casualties, urbanized more densely populated areas were associated with fewer casualties, and road length had positive association with serious injuries. Levine et al. (1995) examined the zonal relationship of motor vehicle crashes to population, employment and road characteristics using census block group as the unit of analysis. Their (Levine et al., 1995) analysis revealed that increased population and miles of major arterial were associated with increased number of crashes per census block group.

The spatial error resulting from the heterogeneity of spatial aggregation motivated the investigation of macro-level crash analysis at relatively homogeneous zones. It is easily understandable that the root-level areal units of the census geography-hierarchical tree will have less amount of spatial heterogeneity. In this paper the analyses were performed using Traffic Analysis Zones (TAZs) as the base spatial unit. TAZs are special areas delineated by state and/or local transportation officials for tabulating traffic-related data and are defined as part of the Census Transportation Planning Package (U.S. Census Bureau website). A Traffic Analysis Zone is a spatial aggregation of census blocks and is in part a function of population (Peters and MacDonald, 2004). As cited by You et al. (1997) the most important criteria used to define TAZs include spatial contiguity, homogeneity, compactness, etc. Also TAZs have commonly been considered as a basis for the aggregate modeling process (Miller and Shaw, 2001). Hadayeghi et al. (2003) studied total and severe crashes at 463 TAZs in the city of Toronto as a function of socio-economic and demographic, traffic demand, and network data variables. De Guevara et al. (2004) developed planning-level crash prediction models for 859 TAZs in Tucson, Arizona considering demographic, socio-economic and roadway characteristics as the predictors.

The study adds to the literature by examining various trip effects on the crash frequencies aggregated at TAZ level. Trip types are vitally important in travel demand modeling process. The modifications of TAZs in Texas are considered during each travel model update when a new base year is established (Traffic Data and Analysis Manual, Texas Department of Transportation). Also, travel demand models (TDMs) are used in Florida and around the country to forecast traffic volumes on highways (Florida Department of Transportation website). Therefore it is speculated that predicting crash frequencies using trip types will help in understanding safety perspectives during the transportation planning level. Also if TAZs are to be defined based on TDMs, this study results point to different approaches when predicting crashes at the zonal level. It is worthwhile to note that the need of incorporating roadway safety considerations in transportation planning process has been emphasized in Transportation Equity Act of 21st Century (TEA-21) and SAFETEA-LU (see Reference for the web link).

3 DATA PREPARATION

The study was based on the following four counties of the state of Florida- Citrus, Hernando, Pasco, and Hillsborough. These four counties constitute a total of one thousand three hundred and forty-nine TAZs. The crash data for the years 2005 and 2006 were used in the study. The Geographic Information System (GIS) shape files (maps) providing crashes as point entities were collected from Florida Department of Transportation (FDOT). Each point (a crash) in the GIS shape file provided several attributes for the corresponding crash. The roadway characteristics were found from separate GIS shape files provided by FDOT. These GIS shape files included roadway segments as line entities. The geographic maps for the study counties were collected from FDOT District Seven Intermodal Systems Development Unit. Each map provided cartographic boundaries of the TAZs within a county. The base spatial unit of the
The study was TAZ and the following steps were taken to aggregate different variables at the TAZ level.

- The spatial join tool in ArcMap 9.2 (by Environmental Systems Research Institute Inc.) was used to assign crashes to the TAZs by joining two GIS shape files- crash map and TAZ cartographic boundary map. It was made sure that both maps had similar GIS coordinate system. Figure 3 shows the spatial distribution of the number of severe crashes (fatal and severe injury crashes) per TAZ in the study counties.
- The streets were similarly spatially attached to the respective TAZs.
- The spatial join procedure allowed each point (a crash) or a line (a roadway segment) feature in the GIS shape files to assign the TAZ id to which the feature was geographically located.
- The next step was to aggregate crash and roadway attributes at the TAZ level. The attributes tables were exported from ArcMap and the aggregation was performed using SAS statistical software (by SAS Institute Inc.).
- Therefore the dataset contained all crash and roadway variables aggregated to a TAZ which was treated as one observation of the dataset.

The number of trip attraction and production per day per TAZ for thirteen different categories were collected from FDOT District Seven Intermodal Systems Development Unit. The final dataset contained the following three main categories of variables- i) crash related variables, ii) variables pertaining to roadways, and iii) different trip attraction and production rates per TAZ. The complete list and descriptive statistics of different responses and predictors are provided in Table 1.

Table 1: Variable description.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Definition</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Min</th>
<th>Max</th>
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<td>TAZ2004</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>Crash severity</td>
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<td>50</td>
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TAZ

Independent variables related to various trip productions and attractions

<table>
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<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
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4 METHODOLOGY

Crash frequencies are non-negative integers which are not normally distributed. It has been widely accepted that a Poisson or negative binomial (NB) model has the ability to estimate the relationships between the number of crashes and covariates. The underlying assumption of Poisson distribution of variance equal to the mean is often violated in the crash count data. Most of the time crash observations have a greater variance than their mean and therefore the data is over-dispersed. Negative binomial models take account this over-dispersion. The negative binomial distribution is characterized by the following mean-variance relationship of a practical observation $Y$.

$$\text{Var}(Y) = \mu + \alpha \mu^2$$

where, $\mu = E(Y)$ and $\alpha$ is the over-dispersion parameter. The presence of over-dispersion is adjusted by the log-linear relationship between the expected number of crash counts in an observation unit $i$, $\mu_i$ and the covariates $X_i$ (Noland and Quddus, 2004).
\[
\ln(\mu_i) = X_i \beta + \varepsilon_i
\]  \hspace{1cm} (2)

where, \( \beta \) is the estimated coefficient vector and \( \varepsilon \) is the random error term representing the effect of omitted unobserved variables. Negative binomial has the following general form of probability mass function.

\[
Pr(Y = y_i) = \frac{\Gamma(y_i + \frac{1}{\alpha})}{\Gamma(\frac{1}{\alpha})\Gamma(y_i + 1)} \left( \frac{\alpha \mu_i}{1 + \alpha \mu_i} \right)^{y_i} \left( 1 + \frac{1}{1 + \alpha \mu_i} \right)^{-\frac{1}{\alpha}}
\]  \hspace{1cm} (3)

where, \( \Gamma(.) \) = gamma function and \( \alpha \geq 0 \). Poisson regression is a limiting condition of NB regression with \( \alpha = 0 \). Wide application of negative binomial regression models as found in various road safety literature (Hauer et al., 1988; Persaud and Dzbik, 1993; Miaou, 1994; Harwood et al., 2000; Hadayeghi et al., 2003; Oh et al., 2003; Noland, 2003; De Guevara et al., 2004; Hadayeghi et al., 2006) implies acceptable practice in modeling crash frequencies and therefore thought to be appropriate to use in this study.

5 DISCUSSION AND RESULTS FROM THE MODEL ESTIMATES

Each model was estimated separately for various trip generations (productions and attractions), roadway characteristics, and finally considering the combined effect of trip and road related variables. The variables which were statistically significant at 95% confidence level were retained in the models. The response variables considered were as follows: total number of crashes (Model A), severe (fatal and severe injury) crashes (Model B), total peak hour crashes (Model C) and pedestrian and bicycle related crashes (Model D). Based on the study done by Wang and Abdel-Aty (2008) and the temporal variations of the aggregated hourly crash frequencies on the weekdays, peak hours were defined as 7:00 to 9:00am and 3:30 to 6:30pm.

The negative binomial model estimates for four different categories of crashes considering trip related predictors only are presented in Table 2. In order to capture the combined effects of various trip productions and trip attractions per TAZ, models were estimated with only two variables- natural logarithmic transformation of total trip productions and total trip attractions per TAZ. The transformations were applied to minimize heteroskedasticity in the data. Table 3 provides different model estimates and goodness of fits for the four models developed considering total trip production and attraction. Table 4 presents estimates of crash models with road related predictors only. Finally models were estimated considering all variables (both trip and road related) and presented in Table 5.

Table 2: NB models of total crashes, severe crashes, peak-hour crashes and pedestrian and bicycle-related crashes with trip-related predictors only.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total Crash (Model A)</th>
<th>Severe Crash (Model B)</th>
<th>Peak-hour Crash (Model C)</th>
<th>Pedestrian and Bicycle related Crash (Model D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate S.E.</td>
<td>Estimate S.E.</td>
<td>Estimate S.E.</td>
<td>Estimate S.E.</td>
</tr>
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<td>0.1118 0.0709</td>
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<td>-0.0004 0.0001</td>
<td>-0.0005 0.0001</td>
<td>-0.0004 0.0001</td>
</tr>
<tr>
<td>HBWP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.0001 0.0001</td>
<td>0.0006 0.0001</td>
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<td></td>
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<td>Peak-hour Crash (Model C)</td>
<td>Pedestrian and Bicycle related Crash (Model D)</td>
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<td>Estimate</td>
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</table>

Table 3: NB models of total crashes, severe crashes, peak-hour crashes and pedestrian and bicycle-related crashes with total trip production and attractions.
Table 5: NB models of total crashes, severe crashes, peak-hour crashes and pedestrian and bicycle-related crashes with all predictors.

<table>
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<th>Variables</th>
<th>Total Crash (Model A)</th>
<th>Severe Crash (Model B)</th>
<th>Peak-hour Crash (Model C)</th>
<th>Pedestrian and Bicycle related Crash (Model D)</th>
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5.1 Total crash model

Total crash model (Model A) retained ten independent variables while assessing the association with trip related variables only (Table 3). No non-home based trips were found significant at 95% confidence level. The total crash trip only model (Table 3) showed negative association with the home based work attractions, home based social recreational productions, and heavy truck productions. The signs for home based work attractions and home based social recreational productions may be explained by the positive attitude toward driving in such circumstances because people driving from home to work most often are relaxed and suffer relatively less mental pressure as opposed to home based work productions. Also for the social recreational trips people often drive with their family and/or children and are usually more careful in such conditions. The second model for total crashes was developed using the total trip productions and total trip attractions only (Table 4). This model provided a better model fit than the first model based on the log-likelihood and deviance value per degrees of freedom (DF). As mentioned previously logarithmic transformation of total trip productions and attractions were used. Both covariates were positively associated with the number of total crashes per TAZ. As the number of trips (attractions and productions) increases, exposure of traffic is thought to increase. This leads to the fact that high exposure will tend to increase the total number of crashes. Hadayeghi et al. (2003) found similar association between vehicle kilometers traveled (VKT) and total crashes per TAZ in the city of Toronto. Also, the positive estimate for VMT was found by Karlaftis and Tarko (1998) while investigating significant variables for crashes involving aged drivers in the counties of Indiana. Both VKT and VMT are considered as measures of exposure. The third model was developed considering road related predictors only (Table 5). Five variables were found significant among which sum of roadway segment length with 25 mph posted speed limit was found to be negatively associated with total crashes. On the contrary, the total segment length with higher posted speed limits (35, 45, and 65 mph) and total number of intersections per TAZ were found to be positively associated with total crashes. The association between higher speed and crash propensity has been well recognized in road safety studies (26-29). Intersections can also suffer an increase in certain type of crashes, particularly rear-end. In
general crashes may increase at intersections due to the complicated maneuvers, and therefore higher number of intersections within a TAZ could lead to increase in total crashes. Finally, total crashes were tested for all variables (both trip and road related predictors) and model estimates were provided in Table 6. Among the seven significant variables five belonged to roadway characteristics and the other two were log of total trip productions and log of total trip attractions. Interestingly the five significant roadway variables were the same as the third model (in Table 5) which was developed for the road related predictors only and the direction of their respective estimates were same in both models. Log of total trip productions and log of total trip attractions were positively associated with the total number of crashes per TAZ. This result conforms to the trip effects as exposure measure from the standpoint that one extra trip will generate an additional count in the traffic volume.

5.2 Severe crash model
Model B was developed considering severe crashes (fatal and severe injury crashes) as the response variable. Trip only model (Table 3) for severe crashes retained five significant variables among which home based work attractions and heavy truck productions were negatively associated with the increase in severe crashes. Perhaps people drive more carefully to work resulting in lower amount of severe crashes. It is also mostly congested period and thus speeds are low in general. Heavy vehicle drivers are usually skilled drivers and are professionally trained to cope with unexpected situations in road-traffic environment which may be an explanation towards decreasing the number of severe crashes. Total trip production and attraction model for severe crashes (Table 4) provided almost similar goodness of fits as compared to the trip only model (in Table 3). The log-likelihood, deviance value/DF and Pearson chi-square value/DF for total trip severe crash model (Table 4) was slightly greater than those of trip only model for severe crashes (Table 3). Severe crash model with the road related predictors (Table 5) had five significant variables at 95% confidence level. Sum of roadway lengths with 35, 45, 55, and 65 mph speed limits were positively associated with severe crashes. This is theoretically acceptable as higher speed tend to influence more severe crashes as previously mentioned. The total number of intersections per TAZ also had positive estimate, however the estimated value (0.0304) was less than that of (0.0452) total crash road only model (Model A in Table 5). The severe crash model using all predictors (road and trip related variables) retained eight significant variables out of which only sum of roadway length with 25 mph speed limit had negative estimate. This means that the increase in roadways with 25 mph posted speed would reduce the number of severe crashes within a TAZ. This is easily explained because severe crashes are less likely to occur at reduced speeds. Also similar to the third model (road only model in Table 4) the coefficient estimate for the total number of intersections within a TAZ was less (0.0191) than that of (0.093) total crash model. This indicates that number of intersections has less effect on severe crashes as compared to the total crashes.

5.3 Peak hour crash model
Peak hour crash model (Model C) presented in Table 3 revealed that home based work attraction, home based social recreational productions and attractions had negative estimates. The suspected effects of home based work attraction and home based social recreational productions have been previously explained. The coefficient for the home based work productions, external internal attractions and airport productions were positive and significant. Perhaps festinated attitude to reach the destination generates such positive correlations. Airport trip could also be related to non familiar travelers (rental cars). Home based other trip attractions and productions retained in the model with opposite signs in their estimates. Theoretical explanation for such cases is difficult at the macro level crash analysis. For the
combined model (Table 6) of peak hour crashes six variables were found significant at 95% confidence level among which only sum of roadway length with 25 mph posted speed limit had negative estimate. Similar to model B sum of roadway lengths with posted speed limits of 35 and 65 mph were positively associated with peak hour crashes. Interestingly the peak hour crash model with road related predictors (Table 5) also had the sum of roadway length with 25 mph posted speed limit estimate to be negatively associated with the peak hour crash frequency. The other three significant variables of the road only model were the sum of roadway length with 45 and 65 mph posted speed limit, and total number of intersections per TAZ, all with positive signs. The hasty attitude of commuters to avoid peak hour congestions or to reach home and/or work places early/in time is one of the inherent characteristics of peak hour driving. This may increase crashes at or near intersections and in high speed (e.g., ≥ 45 mph) roads.

5.4 Pedestrian and bicycle related crash model
Pedestrian and bicycle related crash models (Model D) developed considering trip related variables only (in Table 3) provided similar goodness of fits as model D in Table 4 (i.e., total trip productions and attractions model). Only two independent variables- total roadway segment length with 35 mph speed limit and total number of intersections per TAZ were significant in the pedestrian and bicycle crash model developed for road predictors only (in Table 5). Total roadway segment length with 35 mph speed limit was negatively associated whereas the estimate of ‘total number of intersections per TAZ’ was positive and the highest among the four models (Table 5) which indicates that pedestrian and bicyclists tend to be more involved in crashes at or near intersections. Combined effect model (in Table 6) for pedestrian and bicycle related crashes had three significant positive predictors- log of total trip productions, log of total trip attractions and number of intersections per TAZ; while the total roadway length with 35 mph speed limit being negatively associated with pedestrian and bicycle related crashes as previously found in Table 5.

5.5 Model summary
This paper investigated the four different crash frequency models developed in four different categories to assess the association of various groups of covariates in predicting crash frequencies. It was found that the total crash model (Model A) and peak hour crash model (Model C) were best described by the total trip productions and total trip attractions (in Table 4). On the basis of log-likelihoods, deviance value/DF, and Pearson Chi-square value/DF the severe crash model was best fit by the trip related variables only (in Table 3) and pedestrian and bicycle related crash model was best fit by the road related variables only (in Table 5). Few variable estimates were difficult to explain from theoretical expectations. However, it is speculated that several unmeasured factors in the aggregate level analysis might play some unobserved role.

6 CONCLUSION
Aggregate level analysis for predicting crash frequencies had been contemplated to be an important step in transportation planning and safety research. This paper analyzed various trip types and roadway characteristics to predict crash frequencies per TAZ. The analyses results revealed that total trip productions and total trip attractions provide better model fit for the total and peak hour crashes. On the other hand severe crashes were best associated with different trip related variables whereas pedestrian and bicycle related crash model was best described by the roadway characteristics of a TAZ. This is a significant conclusion that might indicate that different approaches to zonal level analysis should be considered based on the type or severity of crashes being estimated. In addition, the study results conform to the trip
effects as a traffic exposure measure. However, considering trips as exposure measure has certain amount of limitation as the trips vary in length and time. The other exposure measures were not readily available for the TAZs at the time of the study. A few signs of the variable estimates for aggregate level models were difficult to explain. This particular issue has previously been reflected in road safety literatures, e.g., Guevara et al. (2004) argued that for the data aggregated to the TAZ level a theoretically defensible fatal crash model is proved to be most difficult to find.

At the transportation planning stage if TAZs are to be defined based on travel demand models, this study results point to different approaches when predicting crashes at the zonal level. It is speculated that predicting crash frequencies using trip types will help in understanding safety perspectives at early period of transportation planning. The actual trips, however, may be collected on continuous basis to be further investigated. The study may be extended with the longitudinal time frame of a transportation network with appropriate modification of crash prediction models using actual trip ends. Thereby, the study bears the potential for developing both proactive and reactive safety countermeasures in transportation safety planning.

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REFERENCES


Contents session 9  Crash Recording Systems and Safety Auditing II

Karl Kim, University of Hawaii, USA

Influence of Accident Cause on Ranking Hazardous Road Sections
Mahmoud Saffarzadeh, Tarbiat Modares University, Tehran, Iran

Identification of Accident Black Spots on Rural Highways in India: Case Study of Maharashtra State
Dattatraya Tukaram Thube, Public Works Department, Government of Maharashtra, India

Analysis of Risk Factors for Rear-end Collisions by Using Drive-recorder Data
Shigeru Tominaga, College of Science and Technology, Nihon University, Japan

In-Depth Investigation of Severe and Fatal Roadway Crashes in the Emirate of Abu Dhabi-UAE
Jens Thomsen, Health Authority, Abu Dhabi, United Arab Emirates
ELDERLY DRIVER TRAFFIC CITATIONS IN HAWAII, 1996-2006

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Using a comprehensive database of traffic citations in Hawaii, we examine the pattern of violations for elder drivers. We compare the frequencies of citations received by drivers 65 and older to other age groups to determine if there are age-related differences in terms of the types of violations elder drivers are cited for. We look at the age distributions and determine the age specific patterns for eight different types of traffic citations received by elderly drivers (speeding, safety check, restraints, insurance, moving violations, registration, licensing, and driving under the influence of alcohol). After examining the background characteristics of elderly drivers who have received traffic citations, using Poisson regression, we build models to explain the citations as a function of various demographic variables. We found that from normalized violation rates the incidence of traffic citations drops as drivers continue to age. We also include a term to account for citations issued during enforcement campaigns. The analysis concludes with some implications for research, as well as driver education and enforcement programs.

KEYWORDS: Older Drivers, Traffic Citations, Enforcement, Hawaii
1. INTRODUCTION

Increased aging coupled with the frailty of older persons and the U.S.’s dependency on motor vehicles suggests a need for additional research on elderly drivers. While the public is generally concerned about elderly drivers (Robertson and Vanlaar, 2008), studies have examined both elderly driver “performance” as well as “behavior” (Lynman, et.al., 2001) and others have examined the medical outcomes of crash-involved occupants (Li, et.al., 2003). Research has indicated that fatal crashes per mile are much higher for drivers older than 80 years of age (Williams, 2003), and understanding the potential risk of accidents is of a major concern (Garber and Srinivasan, 1991). Safety is complicated by the fact that elderly drivers tend to drive less and may engage in self-regulatory driving practices (Kostyniuk and Molnar, 2008). At issue is the determination of exposure, whether measured in terms of vehicle miles traveled, licensed drivers, or population (Hakamies-Blomqvist, 2004). There has been little focused research on elderly driver traffic citations. This is somewhat surprising given both the availability of computerized traffic citation databases and the ubiquitous character of traffic enforcement activities. Research on citations received by elderly drivers would help to identify the types of mistakes made by elderly drivers and provide some clues as to where driver education efforts might best be applied. Moreover, the review of citation data provides another opportunity to examine issues related to driving cessation issues. In order to receive a citation, not only is there some type of violation of a traffic law, but the individual has to be driving.

In this study, the characteristics of elderly drivers (65 years of age and older) in Hawaii who have received traffic citations over a 10 year period (1996-2006) are closely examined. This builds on previous work which found that elderly drivers in Hawaii have among the highest rates of being classified at fault when involved in accidents (Kim, et.al., 1998) and also much higher rates of being injured or killed than other drivers (Kim, et.al., 1995). Other research in Hawaii also has demonstrated the effects of enforcement on seat belt use (Kim, 1991; Kim and Yamashita, 2004) and has examined the characteristics of those who have received speeding, DUI, and seat belt citations in Hawaii (Kim, et.al., 2009).

The following research questions are addressed in this study:

1. What is the frequency of various types of traffic citations received by elderly drivers in Hawaii?
2. How does the frequency of various traffic citations received by elderly drivers compare with younger drivers?
3. What is the relationship between various types of citations received by elderly drivers and various demographic characteristics?
4. What happens as elderly drivers age in terms of the frequency and normalized (by driver population) frequency of the traffic citations received?
5. What is the relationship between the types of citations received by elderly drivers in Hawaii and their background characteristics?
6. What are the implications of this research for driver education and enforcement in Hawaii?

2. TRAFFIC CITATIONS AND DRIVER BEHAVIOR

Laws may not be enforced and detection of illegal behavior is difficult. While a particular law may be on the books, it may not be enforced. At times, detection of illegal behavior is difficult. Some behaviors such as driving without a license or insurance or even driving under the influence of alcohol or drugs may be difficult to detect. Also, behavior may vary over time and place. Drivers might speed and then slow down as they approach busier, more populated areas. Drivers might also try to avoid areas where police enforcement is more aggressive. Also, drivers might choose to avoid dangerous situations or times of the day in
order to lessen their risks of crash involvement or receiving a traffic citation. Enforcement may also be uneven. During some time periods, such as during the “Click it or Ticket” season, the police may be aggressively enforcing the seat belt law. At other times, the emphasis may be speeding or catching drunk drivers. While it is assumed that there is a relationship between traffic enforcement and safety, the relationship between citations and driver behavior is affected by many different human, technological, and operational factors.

3. DATA AND METHODS
In this study, a comprehensive database of all traffic citations issued in Hawaii over the period 1996-2006 was used. The information was acquired from the State of Hawaii Judiciary. In many respects, Hawaii is an ideal location for studying traffic citation data. It is a small state with a population of approximately 1.2 million persons with approximately 10.2 billion vehicle miles traveled (VMT) (DBEDT, 2009). There are only four different police departments in the entire state and all the data are managed by the Judiciary.

This study began by grouping the key types of traffic violations into eight major categories: 1) speeding; 2) restraints; 3) DUI; 4) Other moving violations; 5) licensing; 6) registration; 7) insurance; and 8) safety check. After compiling the frequencies for each of these violations, the rate of citations was calculated per 100 persons in two broad age groups (elderly) and those less than 65 years of age. Standard statistical tests of significance were applied, and the citations received by elderly drivers (65 and over) in Hawaii were examined in terms of standard demographic elements as well as temporal and location variables. Next the specific age related characteristics for elderly drivers was examined according to the eight main categories of traffic citations. In addition to examining the frequencies of citations received by various age groups, the citations normalized by population were considered. Finally, using Poisson regression models, the odds of receiving individual types of citations as a function of various demographic and other factors were computed.

Batteries of different models were developed and tested using the SAS statistical analysis software package, including General Linear Model (GLM), Negative Binomial (NB), and Poisson. The linear models showed very weak coefficient of determination values. Most of the Negative Binomial models failed to converge. The Poisson models converged and were preferable when attempting to control for overdispersion. Overdispersion occurs when the variance of the data is greater than the mean.

The Poisson regression model adapted to the research on traffic violations can be expressed as follows (Anderson, et.al. 2005):

\[ p(x) = \frac{\mu^x \cdot e^{-\mu}}{x!} \]

where \( p(x) \) was the probability of \( x \) occurrences (citations) in an interval (age), \( \mu \) was the expected value or mean number of occurrences (citations) in an interval (age), and \( e \) was equivalent to 2.71828.

4. FINDINGS
4.1. Frequency of Citations
Table 1 shows that for both elderly as well as younger drivers, the most common type of citation issued in Hawaii is for speeding. Speeding accounts for more than 25.7% of all elderly driver traffic citations and approximately 20% of all citations for younger (aged 16-64) drivers. Safety check violations are the next most common citation for elderly drivers, with 10,449 issued to elderly drivers over the 10 year period. Drivers aged 16-64 amassed 495,432
citations for not having valid safety checks. Seat belt citations were the next most common infraction by elderly drivers, amounting to 16% of all citations issued over the period. For younger drivers, the next most common citation was not having insurance (16.9%) and not having a properly registered vehicle (14.7% of all violations). Registration and insurance problems may be related. Among the citations issued to elderly drivers, 12.97% were for insurance related violations and 10.97 were for registration problems. While 11.9% of the citations were for moving violations (among elderly drivers), 9.7% of the citations were for moving violations among younger drivers in the database. DUI accounted for less than 1 percent of the total violations among elderly drivers, but amounted to 1.77% of the citations among those drivers aged 16-64. In summary, a lower proportion of elderly drivers in Hawaii are cited for safety check, insurance, registration, licensing, and DUI violations than the proportion of younger drivers cited for these types of violations. Surprisingly, a higher percentage of citations among elderly drivers were for speeding, non-restraint use and moving violations compared to younger drivers.

Table 1: Comparison of Elder and Younger Driver Traffic Citations, Hawaii 1996-2006

<table>
<thead>
<tr>
<th>Violation Type</th>
<th>Age 65 - 95</th>
<th>Percentage</th>
<th>Age 16 - 64</th>
<th>Percentage</th>
<th>Z-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speeding</td>
<td>14,885</td>
<td>25.69</td>
<td>508,427</td>
<td>20.03</td>
<td>33.57*</td>
</tr>
<tr>
<td>Safety Check</td>
<td>10,434</td>
<td>18.01</td>
<td>495,432</td>
<td>19.52</td>
<td>-9.08*</td>
</tr>
<tr>
<td>Restraints</td>
<td>9,315</td>
<td>16.08</td>
<td>233,676</td>
<td>9.21</td>
<td>56.14*</td>
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<td>Insurance</td>
<td>7,520</td>
<td>12.98</td>
<td>428,004</td>
<td>16.86</td>
<td>-24.74*</td>
</tr>
<tr>
<td>Moving Violation</td>
<td>6,891</td>
<td>11.89</td>
<td>246,267</td>
<td>9.70</td>
<td>17.57*</td>
</tr>
<tr>
<td>Registration</td>
<td>6,355</td>
<td>10.97</td>
<td>372,502</td>
<td>14.68</td>
<td>-25.00*</td>
</tr>
<tr>
<td>Licensing</td>
<td>2,052</td>
<td>3.54</td>
<td>208,664</td>
<td>8.22</td>
<td>-40.78*</td>
</tr>
<tr>
<td>DUI</td>
<td>482</td>
<td>0.83</td>
<td>44,876</td>
<td>1.77</td>
<td>-17.01*</td>
</tr>
<tr>
<td>TOTAL</td>
<td>57,934</td>
<td>100.00</td>
<td>2,537,848</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at alpha level of 0.05

4.2. Differences Between Elderly and Young Drivers

In Table 2, the number of citations per 100 persons is calculated. This shows that elderly drivers receive fewer citations on a per capita basis than the younger drivers in the database. Over the 10 year period, elderly drivers received approximately 9.25 speeding citations per 100 persons, while younger drivers received 64.45 speeding citations per 100 persons. Similarly, the rate of seat belt citations for younger drivers is approximately 29.6 while the rate for elderly drivers is only 5.78 per 100 persons. The rate of DUI violations for elderly drivers is 0.3 per 100 persons while the rate per 100 persons for younger drivers is 5.69. The rate of violation for moving violations for elderly drivers is 4.28 per 100 persons, versus 31.22 per persons for younger drivers. While elderly drivers have approximately 6.48 citations per 100 persons for safety check violations, 4.67 citations per 100 persons for not having insurance, and 3.95 citations per 100 persons for registration violations, the rates of violation among younger drivers is much higher (62.8, 54.25, and 47.22, respectively). Put another way, the total citation rate for elderly drivers is 35.95 citations per 100 persons, while the rate for younger drivers is 321.69 per 100 persons, almost 10 times greater than the rate for elderly drivers.
Table 2: Citation Rates per 100 Persons for a 10 Year Period

<table>
<thead>
<tr>
<th>Violation Type</th>
<th>age 65 - 95</th>
<th>age 16 – 64</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Received Citation</td>
<td>Rate per 100 person</td>
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<tr>
<td>Speeding</td>
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<td>9.24</td>
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<td>Safety Check</td>
<td>10,434</td>
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<td>Restraints</td>
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<td>Insurance</td>
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<td>4.67</td>
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<tr>
<td>Moving Violation</td>
<td>6,891</td>
<td>4.28</td>
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<td>Registration</td>
<td>6,355</td>
<td>3.94</td>
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<tr>
<td>Licensing</td>
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<td>1.27</td>
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<td>DUI</td>
<td>482</td>
<td>0.30</td>
</tr>
<tr>
<td>TOTAL</td>
<td>57,934</td>
<td>35.95</td>
</tr>
</tbody>
</table>

4.3. Background Characteristics of Cited Elderly Drivers

Table 3 shows the various types of citations received by elderly drivers tabulated against demographic and other variables. Some general observations are in order. As elderly drivers age, the number of citations received generally decrease. While there were 6,731 speeding tickets for those aged 65-69, only 325 speeding citations were issued for those driver 85 years and older. Across all eight types of violations many more elderly males than females receive traffic citations. Citations are generally proportionate to population; with Honolulu having the most, followed by Hawaii, Maui and Kauai County. The worst month for speeding citations is March. For seat belt citations, the worst month is May. Other types of citations appear more evenly distributed across time. In general, Sundays have the lowest number of citations for elderly drivers, while Tuesdays, Wednesdays and Thursdays produce the highest volume of citations for elderly drivers.

4.4. Effects of Aging on Citations

Figures 1a, 1b, and 1c, demonstrate that overall, the frequency of citations drop by age. By examining the shape of these curves, the differences between younger elderly drivers and older elderly drivers also emerges. Speeding, safety check, restraints, moving violations, and insurance related violations have the strongest age related effects, in that decreases occur more prominently especially during the earlier age groups (65-75). DUI and licensing violations are low among all age groupings. The rates of violation across all types begin to converge between 80 and 85 years of age. This is especially apparent in Figure 1c which shows frequency of citations divided by the total population in each age group.
<table>
<thead>
<tr>
<th>Table 3: Citations by Elderly Driver Characteristics</th>
<th>Speeding</th>
<th>Safety Check</th>
<th>Restraints</th>
<th>Insurance</th>
<th>Moving Violation</th>
<th>Registration</th>
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<th>DUI</th>
</tr>
</thead>
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<td>TOTAL</td>
<td>14,885</td>
<td>10,434</td>
<td>9,315</td>
<td>7,520</td>
<td>6,891</td>
<td>6,355</td>
<td>2,052</td>
<td>482</td>
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<td></td>
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<tr>
<td>65-69</td>
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<td>4,460</td>
<td>3,894</td>
<td>2,903</td>
<td>3,029</td>
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<td>1,908</td>
<td>1,715</td>
<td>501</td>
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<td>1,801</td>
<td>1,654</td>
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<td>1,146</td>
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<td>672</td>
<td>606</td>
<td>630</td>
<td>180</td>
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</tr>
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<td>695</td>
<td>602</td>
<td>564</td>
<td>532</td>
<td>161</td>
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<td>777</td>
<td>640</td>
<td>597</td>
<td>538</td>
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<td>639</td>
<td>640</td>
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<td>579</td>
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<td>511</td>
<td>642</td>
<td>613</td>
<td>507</td>
<td>171</td>
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<td>416</td>
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<td>730</td>
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<td>554</td>
<td>460</td>
<td>433</td>
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<td>DAY OF WEEK</td>
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</tr>
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<td>1,006</td>
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<td>800</td>
<td>628</td>
<td>682</td>
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<td>1,736</td>
<td>1,594</td>
<td>1,184</td>
<td>1,116</td>
<td>1,053</td>
<td>317</td>
<td>63</td>
</tr>
<tr>
<td>Thursday</td>
<td>2,761</td>
<td>1,533</td>
<td>1,422</td>
<td>1,092</td>
<td>1,120</td>
<td>946</td>
<td>321</td>
<td>67</td>
</tr>
<tr>
<td>Friday</td>
<td>2,190</td>
<td>1,571</td>
<td>1,441</td>
<td>1,180</td>
<td>1,131</td>
<td>918</td>
<td>325</td>
<td>85</td>
</tr>
<tr>
<td>Saturday</td>
<td>1,271</td>
<td>1,216</td>
<td>917</td>
<td>979</td>
<td>784</td>
<td>775</td>
<td>273</td>
<td>84</td>
</tr>
</tbody>
</table>
4.5. Modeling Age Related Effects
Table 4 shows the significant parameters of Poisson models. The Poisson model provides a different view of the relationship between aging and traffic citations. Speeding, Registration, and DUI have negative effects, indicating that as elderly drivers age, the incidence of traffic citations decreases. Safety, Insurance, and License are the opposite; they have positive effects, indicating that as elderly drivers age, the incidence of traffic citations increases.
Table 4: Poisson Estimated Values for Age-Related Effects on Citations

<table>
<thead>
<tr>
<th>Model</th>
<th>Estimated Value</th>
<th>Pearson Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>Age</td>
</tr>
<tr>
<td>Speeding</td>
<td>-0.2395*</td>
<td>-0.0156*</td>
</tr>
<tr>
<td>Safety</td>
<td>-2.0314*</td>
<td>0.0044*</td>
</tr>
<tr>
<td>Restraint</td>
<td>-1.8877*</td>
<td>0.0008</td>
</tr>
<tr>
<td>Insurance</td>
<td>-3.8443*</td>
<td>0.0249*</td>
</tr>
<tr>
<td>Moving</td>
<td>-1.8507*</td>
<td>-0.0039</td>
</tr>
<tr>
<td>Registration</td>
<td>-1.6835*</td>
<td>-0.0073*</td>
</tr>
<tr>
<td>License</td>
<td>-5.7875*</td>
<td>0.0337*</td>
</tr>
<tr>
<td>DUI</td>
<td>1.8746*</td>
<td>-0.0944*</td>
</tr>
</tbody>
</table>

*Significant at alpha level of 0.05

5. DISCUSSION

There are some advantages to conducting this type of research in Hawaii, an island state which conjures images of swaying palms and white sandy beaches but also has one of the fastest aging populations in the U.S. The State of Hawaii Office of Aging reported that from 1980 to 2000, the elderly population in Hawaii increased by roughly 82% while total population only grew by approximately 26% (Executive Office of Aging, 2007). In addition to advantages of being an island state with an isolated population, this paper builds on earlier research associated with traffic safety and enforcement (Kim, 1991; Kim and Yamashita, 2004; Kim, et.al., 2009).

In spite of the high compliance with seat belt laws, more than 9,315 elderly drivers received a seat belt violation in Hawaii over this 10 year period of study. There were 14,885 elderly drivers who received speeding tickets. If the combined total of speeding tickets and other moving violations are considered, there were a total of 21,776 serious violations committed by elderly drivers.

Especially when considered on a per 100 person basis, the rates of violation for elderly drivers are much lower than other age groups. None of the per-person rates come close to those for younger drivers. The highest citation rates were for speeding, safety check, restraints, while the lowest violation rates among elderly drivers were for DUI, licensing, and registration violations. Insurance and moving violation rates were in the middle. The normalized violation rates indicate that the incidence of traffic citations drops as drivers continue to age.

As a test to determine if the influence of enforcement levels would explain the daily citations for the different violation types, a graphic representing the number of citations by year was closely examined. Figure 2 shows the daily citation issued for speeding, while figure 3 depicts the citation issued for non-use of restraints. The descriptive statistics were calculated for each type of citation by County. Days on which more citations than the mean plus two standard deviations were defined as heavy enforcement days. There were some statistically significant differences between enforcement and non-enforcement days. On non-enforcement days, proportionately more of the younger older drivers were more likely to receive speeding tickets, while on enforcement days; proportionately older elder drivers received speeding tickets. A similar pattern emerges with restraint use violations, where, proportionately older drivers receive citations on enforcement days (also defined as mean plus 2 standard deviations) than on non-enforcement days. Table 5 compares the number of citations received for speeding and non-use of restraints between enforcement and non-enforcement days in Honolulu.
Figure 2: Daily Citations Issued for Speeding in Hawaii

Figure 3: Daily Citations Issued for Non-use of Restraints in Hawaii
Table 5: Speeding and Non-Use of Restraints Citations in Honolulu.

<table>
<thead>
<tr>
<th>Description</th>
<th>Non Enforcement Days</th>
<th>Enforcement Days</th>
<th>Z-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>%</td>
<td>Number</td>
</tr>
<tr>
<td>Speeding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>3700</td>
<td>45.70</td>
<td>717</td>
</tr>
<tr>
<td>70-74</td>
<td>2274</td>
<td>28.08</td>
<td>560</td>
</tr>
<tr>
<td>75-79</td>
<td>1379</td>
<td>17.03</td>
<td>374</td>
</tr>
<tr>
<td>80-84</td>
<td>583</td>
<td>7.20</td>
<td>176</td>
</tr>
<tr>
<td>85+</td>
<td>161</td>
<td>1.99</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>8097</td>
<td></td>
<td>1897</td>
</tr>
<tr>
<td>Non-Use of Restraints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>1367</td>
<td>41.46</td>
<td>399</td>
</tr>
<tr>
<td>70-74</td>
<td>924</td>
<td>28.03</td>
<td>295</td>
</tr>
<tr>
<td>75-79</td>
<td>585</td>
<td>17.74</td>
<td>240</td>
</tr>
<tr>
<td>80-84</td>
<td>302</td>
<td>9.16</td>
<td>112</td>
</tr>
<tr>
<td>85+</td>
<td>119</td>
<td>3.61</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>3297</td>
<td></td>
<td>1089</td>
</tr>
</tbody>
</table>

*Significant at alpha level of 0.05

6. IMPLICATIONS

Before describing the implications of this research, there are some limitations to be noted. First, the database may not have captured all of the elderly drivers stopped by the police. Some of them may have been let go without being given a traffic citation. Especially in a community such as Hawaii, with a large Asian community, there is the possibility that elderly drivers may receive preferential treatment by the police. Second, there may be some spatial bias associated with where the elderly live and where they travel, compared to the overall population. The land use, traffic, and other factors affecting travel behavior and the risks of being stopped or cited for traffic violations need further examination. Clearly, enforcement activity could have an affect on the incidence of traffic citations.

Table 6: Numbers of Citation per Miles Traveled by Age Group

<table>
<thead>
<tr>
<th>Violation Type</th>
<th>Received Citation</th>
<th>Rate by 50% of miles traveled per-vehicle</th>
<th>Rate by 25% of miles traveled per-vehicle</th>
<th>Rate by 10% of miles traveled per-vehicle</th>
<th>Received Citation</th>
<th>Rate by miles traveled per-vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speeding</td>
<td>14,885</td>
<td>0.30</td>
<td>0.60</td>
<td>1.49</td>
<td>508,427</td>
<td>5.09</td>
</tr>
<tr>
<td>Safety Check</td>
<td>10,434</td>
<td>0.21</td>
<td>0.42</td>
<td>1.04</td>
<td>495,432</td>
<td>4.96</td>
</tr>
<tr>
<td>Restraints</td>
<td>9,315</td>
<td>0.19</td>
<td>0.37</td>
<td>0.93</td>
<td>233,676</td>
<td>2.34</td>
</tr>
<tr>
<td>Insurance</td>
<td>7,520</td>
<td>0.15</td>
<td>0.30</td>
<td>0.75</td>
<td>428,004</td>
<td>4.29</td>
</tr>
<tr>
<td>Moving Violation</td>
<td>6,891</td>
<td>0.14</td>
<td>0.28</td>
<td>0.69</td>
<td>246,267</td>
<td>2.47</td>
</tr>
<tr>
<td>Registration</td>
<td>6,355</td>
<td>0.13</td>
<td>0.25</td>
<td>0.64</td>
<td>372,502</td>
<td>3.73</td>
</tr>
<tr>
<td>Licensing</td>
<td>2,052</td>
<td>0.04</td>
<td>0.08</td>
<td>0.21</td>
<td>208,664</td>
<td>2.09</td>
</tr>
<tr>
<td>DUI</td>
<td>482</td>
<td>0.01</td>
<td>0.02</td>
<td>0.05</td>
<td>44,876</td>
<td>0.45</td>
</tr>
</tbody>
</table>

Relative to other age groups, there is evidence of lower rates of violation among elderly drivers. Table 6 shows age-specific levels of exposure. The exposure rate is based on miles traveled per-vehicle in Hawaii during the period of 1996-2006 (DBEDT, 2009). Because of the lack of data specific to the miles traveled by elder drivers, elderly drivers were assumed to drive 50%, 25% and 10% of miles traveled per-vehicle, while younger drivers had 100% of
that value. The results confirm that rates of violation among elderly drivers are lower than their counterparts, even adjusting for their lower levels of miles traveled per-vehicle.

Even though the estimated rates are low, there is reason to focus on both speeding and moving violations as well as seat belt use since there is much evidence to suggest that these crash involvements involving these types of actions produce higher levels of injury (Hakamies-Blomqvist, 2004; Kim, et.al., 1995). Perhaps there is need for more educational programs to encourage belt use as well as more detailed research and analysis of the types of moving violations committed by elderly drivers. It might also be useful to develop information campaigns directed towards the elderly focusing on seat belt use, speeding, and moving violations.

More effort might go towards the identification of high risk elderly drivers. By using the citation database to identify either repeat offenders or those which commit really serious infractions, it is clear that there are significant differences between elderly drivers, not just in terms of the differences between 65 year olds and 85 year olds, but also between drivers of the same age.

The licensing, registration, safety check, and insurance citations warrant further investigation. Are the unlicensed drivers simply those who failed to renew their driving privileges or are they drivers whose licenses were suspended? More research needs to be conducted on this topic. These factors may also be related to economic considerations as the costs of insurance and motor vehicle upkeep may also be burdensome for those on fixed incomes.

7. CONCLUSIONS
This analysis contributes to understanding the safety needs of elderly drivers in several ways. First, it helps to identify the types of violations that elder drivers in Hawaii received. Second, this study demonstrates, at least on a per person basis, the rate of traffic citations for elderly drivers is much lower than for older drivers. This is due in part to their lower exposure but also due to behavioral differences. Still, there are concerns about speeding, restraint use, and moving violations that warrant further attention. It would be useful to compare these findings to other jurisdictions.

The age related changes are most dramatic for speeding and restraint use. It would be interesting to see how these effects change over time, both because the proportion of elderly drivers may increase or decrease as the elderly population changes. Citations provide some clues as to both the types of errors and violations made by elderly drivers, but also levels of exposure. The decrease in citation rate is due to both changed behaviors as well as reduced exposure.

REFERENCES


Influence of Accident Cause on Ranking Hazardous Road Sections

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Abstract

Accidents do not occur by chance. An accident results from the complicated interaction of various causes. Identification and prioritization of hazardous road sections can not be achieved without determining effects of these causes on accident occurrence. In this paper, having effective factors in accident occurrence known, a model was proposed for identifying and prioritizing hazardous road sections. This model was developed based on nature of accident and using multi-attribute decision-making methods. One of the most important results of this research is that outputs from prioritizing hazardous road sections based on accident cause may be more accurate and different from those of current models which don’t take accident cause into account.

According to the developed model, a segment may be compared to another and be identified to be high accident-prone with the same cause, whereas, the total number of accidents occurred in the former may be less than that in the latter. The model was evaluated based on the real data collected from highway segments in Tehran.

Keywords: Road Safety; Cause of accident; Ranking; vehicle

1. Introduction

Road safety is a major concern in the present situation. It has been estimated that over 300,000 persons die and 10-15 million persons are injured every single year in road accidents throughout the world [Mandloi and Gupta, 2003]. Therefore, it is necessary to identify hazardous locations on roads commonly termed as black spots for improving safety. But due to the executive constraints, improvement all of these locations may not be possible. So it is required to develop a suitable method to rank hazardous locations.

2. Literature

So far, there have been different models for identifying and prioritizing high crash road
segments which have approached the issue of prioritization based on different criteria. A brief review of these models is as follows:

The crash frequency method summarizes the number of crashes for spot locations [Traffic Institute 1999, NCHRP 2000, Hallmark et al. 2002]. Locations are ranked by descending crash frequency and those with more than a predetermined number of crashes are classified as high-crash locations to be further scrutinized for statistical significance.

Closely related to the Crash Frequency Model, the Crash Density Model summarizes the number of crashes per kilometer for highway segments [SEMCOG 1997, Hallmark et al. 2002]. Locations are ranked by descending crash density and those with more than a predetermined density of crashes are classified as high-crash locations to be further scrutinized for statistical significance.

The crash rate method does account for both exposure and the total number of crashes [NCHRP 1986, Hallmark et al. 2002]. For links, crash rate is a function of the number of crashes, traffic volume, and the length of the segment. At nodes, crash rate is a function of the number of crashes and daily entering vehicles. Locations with higher than a predetermined rate are classified as high crash locations.

The Crash Severity Model accounts for monetary losses of crashes by considering and then weighting crashes at a location based on the resulting degree of injury [Layton 1996, Hallmark et al. 2002]. Fatal and injury crashes are usually weighted more heavily than possible or minor injuries and Property Damage Only crashes. This allows for the severity of accidents to be considered.

The rate quality control method consists of a simple statistical test that is applied to the crash rate at a particular location (intersection/roadway) to determine whether it is significantly different (abnormally high) than the average crash rate of other similar locations [Hallmark et al. 2002].

The Frequency-Rate Model is a combination of the Crash Frequency and Crash Rate Methods [Homburger et al. 1996, Hallmark et al. 2002]. Locations are first ranked by Crash Frequency and the worst locations re-ranked using Crash Rate.

The Severity-Rate Model combines the Crash Severity and Crash Rate Models [Hallmark et al. 2002]. In this model, an Equivalent Property Damage Only (EPDO) number is calculated (as in the Crash Severity Model) and then divided by volume (e.g., MEV or MVM) to obtain an EPDO rate for each road segment.

The Empirical Bayes Model attempts to overcome the difficulties with some of the conventional techniques [Persuad et al. 1999, Hallmark et al. 2002]. This model controls the randomness of crash data by estimating the long-term mean number of crashes at a location. This model is used for predicting crashes in the future and then ranking them by predicting the number of crashes.

3. Theory of Model

The formation process of different models to prioritize the high crash road segments shows that each one has been used to make the previous one more complete. These models are generally based on the parameters of accident frequency, accident severity, accident rate and the accident prediction models. These models, however, all suffer from some logical and technical deficiencies which can make the prioritizing process erroneous and decrease the positive effects of safety improvements. Since safety improvements require very high costs, making errors in prioritizing high crash road segments will lead to wasting national resources. In general, the deficiency in identifying and prioritizing high crash road segments which may lead to errors in the prioritization results of current models may be as follows:

a. Using total accidents "with different causes" when prioritizing high crash road segments,
b. Not taking into account the traffic volume parameter for through traffic in some of the models,
c. Not taking the accident severity factor into account in some of the models, and
d. Not including the accident cause for prioritizing high crash road segments.
Thus, proposing a more comprehensive model seems more necessary which may eliminate the
previous model's deficiencies and make the prioritization process more accurate when making
safety improvements.
For identifying any phenomenon, it should be considered factors that affect it. The "road
accident" as a phenomenon is not an exception. Since accident occurrence results from
various factors, it is not easy to identify accident causes. But it is possible to identify general
accident causes with technical methods and accepting allowable error. By preparing the
ground for long-term planning to eliminate high accident-proneness of some specific
segments of road, a great deal of time and money can be saved in safety improvements. This
is due to the fact that finding an appropriate strategy to eliminate high accident-proneness of
road segments requires finding the accident cause. According to this theory, a high crash road
segment is the one in which all causes are being equal and the accident frequency is more than
a cut-off point. By the same token, a segment cannot be identified as high crash based only on
its high accident frequency from various causes.
For example, suppose 5 accidents happened in every two segments with similar
characteristics. The Causes of every accident in first segment respectively are high speed,
shortage of skid resistance, shortage of sight distance, brake failure and driver error and in
second one is just shortage of skid resistance. So due to causes of all accidents in second
segment are the same (shortage of skid resistance), this segment is more hazardous than the
first one. The main difference between the BAC Model and the previous models lies in the
attention it pays to the accident cause as a parameter for prioritizing high crash road segments;
a parameter which has been ignored by previous models. Along with the accident causes, in
BAC Model other parameters such as accident frequency, accident severity and the traffic
volume are taken into account simultaneously.
Since accident analysis should be done discretely, solving this problem can be done by using
Multiple Attribute Decision Making (MADM) methods. Meanwhile, due to the
multidimensional nature of prioritization of the high crash road segments, the MADM
Methods have a high degree of efficiency. These methods are generally proposed to facilitate
decision making and to increase the validity and precision of the decisions made by decision
makers [Yoon and Hwang 1995].

4. Model Development
Considering the proposed theory, in this section the prioritizing stages of the high crash road
segments with new Model are discussed.
Step 1- Data gathering
At this stage, both physical and traffic characteristics of the road are determined and analyzed.
In addition, trip generation and attraction centers must be identified. This can influence road
segmentation and determining the length of each segment. Also, accidents and traffic data
must be collected. Since, inadequate road conditions both physical and traffic are amongst the
most important factors causing accidents, this stage is therefore, an important one when
prioritizing based on accident causes.
Step 2- Segmentation of the study area
Road accident analysis produces better results through site segmentation. Because of the
complexities in data interpretation of accidents in segments with different lengths, it is highly
recommended to use segments with constant lengths for segmentation of road [Geurts and
Wets 2003]. In general, where traffic and physical characteristics change drastically and also
sites with more accident frequency compared to the whole road length, new segment should be defined. It should be noted that segmentation operations may change with road conditions. Finally, each segment is given a specific code [Pulugurtha and Nambisan 2003].

**Step 3- Categorization of accident statistics**

Having collected all accident data in a specific time period, the data are mapped on the area of interest. In general, factors such as road factors, human factors, etc; may affect high accident-proneness of a segment. Regarding the process of prioritization in this model which is based on accident frequency, accident severity and accident cause, at this stage the accident data should be categorized for each road segment based on the accident cause and accident severity. The number of decision attributes depends on the factors affecting the accident occurrence. Also, accident severity which is an important parameter in the model is divided into Fatal, Injury and Property Damage Only.

**Step 4- Weighting each criterion**

In any area, based on its local conditions, the factors influencing the accident occurrence should be studied and weighted. This is done by studying the accident data, by preparing a questionnaire or by interviewing safety experts; otherwise the information given in this paper may be used. In so doing, the relative weight of each criterion for prioritization is shown by \( w_j \). The weight vector for decision attributes is given by:

\[
W_{n 	imes 1} = \begin{bmatrix}
  w_1 \\
  w_2 \\
  \vdots \\
  w_n 
\end{bmatrix}
\]

So that:

\[
\sum_{j=1}^{n} w_j = 1
\]

**Step 5- Ranking the segments**

First, for prioritizing the high crash road segments, the accident frequency of each segment based on the accident severity and accident cause is shown by a decision matrix called "F" in which:

\[
F = (f_{ij})_{m\times n} = \begin{bmatrix}
  x_1 & x_2 & \cdots & x_n \\
  A_1 & f_{11} & f_{12} & \cdots & f_{1n} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  A_m & f_{m1} & f_{m2} & \cdots & f_{mn} 
\end{bmatrix}
\]

Where:

\( m \) = number of road segments,
\( x_j \) = the model's considered attributes for prioritizing high crash road segments, and
\( f_{ij} \) = accident frequency in the segment \( A_i \) for the attribute \( x_j \).

It should be noted that in this matrix, the set \( X = \{x_1, x_2, \ldots, x_n\} \) consists of two levels of accident causes and accident severity degrees (Fatal, Injury and Property Damage Only). Then the Matrix "F" is turned into an Expectation Matrix "R" and is given by:
\[
    r_{ij} = \frac{f_{ij}}{\sum_{j=1}^{n} f_{ij}} \times \frac{\sum_{i=1}^{n} f_{ij}}{v_i} = \frac{f_{ij}^2}{v_i} \quad i = 1, 2, ..., m \quad j = 1, 2, ..., n
\]  

(4)

Where:

- \( r_{ij} \) = high accident-proneness of segment \( A_i \) for attribute \( x_j \), and
- \( v_i \) = volume of through traffic from segment \( A_i \) in the accident period per 1000 vehicles.

In this equation, the probability of accidents occurring from a specific cause and from the traffic is taken into account using the probability principle. It should be noted that the decision attributes are of the same dimensions and there is no need for normalizing the decision matrix.

Expectation Matrix "R" is shown by:

\[
    R = (r_{ij})_{m \times n}
\]

(5)

Using Equation (6), the Prioritization Matrix "\( F' \)" is obtained by multiplying matrix "R" by the weight vector "W", so that:

\[
    F'_{m \times 1} = R_{m \times n} \times W_{n \times 1} = \begin{bmatrix} f'_1 \\ f'_2 \\ \vdots \\ f'_m \end{bmatrix}
\]

(6)

Where:

- \( f'_i \) = the importance of segment \( A_i \) with respect to high accident-proneness

Finally, by ranking the elements of prioritization matrix "\( F' \)" in an ascending or descending order, the priority of each segment can be determined for making safety improvements. In this way, the segment with highest accident-proneness is ranked as the first priority. All of the stages of BAC Model are shown in Fig. 1.
5. Model Evaluation

Using real data may not be present all BAC Model capabilities such as being sensitive to cumulative accidents by the same cause, so the performance of the BAC Model is assessed through an example and is compared with current models.

Suppose we are going to prioritize the high crash segments of a road for safety improvements. The road of interest has the following characteristics:

a. It consists of five specific segments with the same length (It is assumed that the length of each segment has been technically and logically determined in advance).

b. The road width is the same for all the defined segments.

c. Categorization of accident statistics in each segment is based on accident severity and cause.

d. The time period for accident analysis is assumed to be constant.

Categorization of accident statistics in each road segment which is based on severity and traffic and physical characteristics of each road segment is shown in Table 1.

### Table 1: Traffic and physical characteristics of the road segments and categorizing accidents based on severity

<table>
<thead>
<tr>
<th>High crash road segments</th>
<th>Distance from origin (kilometers)</th>
<th>Length of segments (kilometers)</th>
<th>Accident frequency in each segment</th>
<th>Annual Average Daily Traffic (AADT) (vehicles per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>5</td>
<td>5</td>
<td>36</td>
<td>8000</td>
</tr>
<tr>
<td>$A_2$</td>
<td>10</td>
<td>5</td>
<td>48</td>
<td>9000</td>
</tr>
<tr>
<td>$A_3$</td>
<td>15</td>
<td>5</td>
<td>30</td>
<td>9000</td>
</tr>
<tr>
<td>$A_4$</td>
<td>20</td>
<td>5</td>
<td>36</td>
<td>8600</td>
</tr>
<tr>
<td>$A_5$</td>
<td>25</td>
<td>5</td>
<td>36</td>
<td>8600</td>
</tr>
</tbody>
</table>

5.1. Prioritizing High Crash Road Segments Based on Current Models
Using the data in Table 1, the current models can be employed to prioritize defined segments. The Accident Frequency Model gives priority by determining the accident frequency mean in each segment. In the Accident Rate Model, the accident rate in each segment is obtained and the segments with highest accident-proneness are identified. Also, to prioritize by Accident Severity Model, importance of fatal accident is considered 4 times of injury accident and 12 times of property damage accident [Kautzman 2001]. The results obtained from these models are shown in Table 2.

5.2. Prioritizing High Crash Road Segments Based on BAC Model

Considering the assumption made in the example, the first and second stages of prioritization is already done. Based on previous research, the factors which cause road accidents are generally four types [Ayati 1992, Mahmoodi Moazzam 2002]:

a) Road factors,
b) Environmental factors,
c) Vehicle factors, and
d) Human factors.

Therefore, in this example, these factors are the decision attributes. The accident severity parameter in the model is also divided into three groups of Fatal, Injury and Property Damage Only and is a sub-criterion in the prioritization process. The hierarchy of attributes for prioritizing high crash road segments can be shown as in Fig. 2.

The relative weight of these factors of road, environmental, vehicle and human is shown by $\alpha_i$ and the relative weight for severity degrees is shown by $\beta_k$.

Thus using Equation (7), the final weight for each criterion is obtained by multiplying the weight of each factor causing accidents by the weight of accident severity degrees.

$$w_j = \alpha_i \times \beta_k \quad , \quad i = 1,2,3,4 \quad , \quad k = 1,2,3 \quad , \quad j = 1,2,\ldots,12$$  \hspace{1cm} (7)

Where:

- $i=\text{indicator of accident cause weight},$
- $k=\text{indicator of accident severity weight},$ and
- $j=\text{indicator of the final weight of each criterion}.$

This paper assumes that the relative weight for the factors of road, environmental, vehicle and human is 0.26, 0.22, 0.21 and 0.31 respectively. From previous studies, the relative weight for accident severity degrees including Fatal, Injury and Property Damage Only are 0.75, 0.19
and 0.06 respectively which have been obtained from the Geometric Mean Method [Kautzman 2001, Ghodsipoor 2005]. Thus, using Equation (7) and the given weights, the elements of vector "W" are shown as the following:

\[
\begin{align*}
    w_{1,1} &= 0.2, & w_{2,1} &= 0.05, & w_{3,1} &= 0.02, & w_{4,1} &= 0.17, & w_{5,1} &= 0.04, & w_{6,1} &= 0.01, \\
    w_{7,1} &= 0.16, & w_{8,1} &= 0.03, & w_{9,1} &= 0.01, & w_{10,1} &= 0.23, & w_{11,1} &= 0.06, & w_{12,1} &= 0.02.
\end{align*}
\]

From using Equation (3), the next step is to form decision matrix "F" as shown below:

\[
F = \begin{bmatrix}
    A_1 & A_2 & A_3 & A_4 & A_5 \\
    1 & 3 & 4 & 1 & 2 & 4 & 3 & 4 & 3 & 2 & 5 & 4 \\
    3 & 3 & 4 & 4 & 5 & 6 & 4 & 5 & 4 & 2 & 4 & 4 \\
    1 & 0 & 2 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 20 & 1 \\
    1 & 4 & 3 & 2 & 1 & 4 & 3 & 3 & 4 & 4 & 2 & 5 \\
    1 & 3 & 4 & 1 & 2 & 4 & 3 & 4 & 3 & 2 & 5 & 4
\end{bmatrix}
\]

Then, by using Equation (4) and (5), the matrix "F" becomes an Expectation Matrix called "R".

\[
R = \begin{bmatrix}
    0.125 & 1.125 & 2 & 0.125 & 0.5 & 2 & 1.125 & 2 & 1.125 & 0.5 & 3.125 & 2 \\
    1 & 1 & 1.778 & 1.778 & 2.778 & 4 & 1.778 & 2.778 & 1.778 & 0.444 & 1.778 & 1.778 \\
    0.111 & 0 & 0.444 & 0.111 & 0.111 & 0.111 & 0.111 & 0.111 & 0 & 0.111 & 44.444 & 0.111 \\
    0.116 & 1.86 & 1.047 & 0.465 & 0.116 & 1.86 & 1.047 & 1.047 & 1.86 & 1.86 & 0.465 & 2.907 \\
    0.116 & 1.047 & 1.86 & 0.116 & 0.465 & 1.86 & 1.047 & 1.86 & 1.047 & 0.465 & 2.907 & 1.86
\end{bmatrix}
\]

Finally, by using Equation (6) the weight of each segment is obtained with its high accident-proneness and its priority for making safety improvements is determined from the Prioritization Matrix "F'", Where:

\[
F' = \begin{bmatrix}
    0.776 \\
    1.369 \\
    2.771 \\
    0.971 \\
    0.722
\end{bmatrix}
\]

In Which:

\[
    f'_1 = 0.776, \quad f'_2 = 1.369, \quad f'_3 = 2.771, \quad f'_4 = 0.971, \quad f'_5 = 0.722
\]

From the BAC Model, the alternative with the highest degree of importance is given top priority for making safety improvements. Thus, the priorities of the high crash road segments are...
are as follows:

\[ A_3 \succ A_2 \succ A_4 \succ A_1 \succ A_5 \]

Table 2 compares the results of prioritizing high crash road segments from current models to those from the BAC Model.

<table>
<thead>
<tr>
<th>Road Segments Priority</th>
<th>Accident Frequency Model</th>
<th>Accident Rate Model</th>
<th>Accident Severity Model</th>
<th>BAC Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( A_2 )</td>
<td>( A_2 )</td>
<td>( A_2 )</td>
<td>( A_3 )</td>
</tr>
<tr>
<td>2</td>
<td>( A_1, A_4, A_5 )</td>
<td>( A_1 )</td>
<td>( A_4 )</td>
<td>( A_2 )</td>
</tr>
<tr>
<td>3</td>
<td>( A_3 )</td>
<td>( A_4, A_5 )</td>
<td>( A_1, A_5 )</td>
<td>( A_4 )</td>
</tr>
<tr>
<td>4</td>
<td>–</td>
<td>( A_3 )</td>
<td>( A_3 )</td>
<td>( A_1 )</td>
</tr>
<tr>
<td>5</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>( A_5 )</td>
</tr>
</tbody>
</table>

It is therefore, obvious, that in the BAC Model despite its high accident frequency, segment \( A_2 \) is not identified as the highest accident-prone segment. Since, cause of the accidents of the same type played an important role in prioritizing high crash road segments; therefore, segment \( A_5 \) is identified as the one with the highest degree of accident-proneness. Comparing segments \( A_1 \) and \( A_5 \), it is clear that despite the equal frequency of accidents, accident severity and cause, BAC Model is sensitive to the volume of through traffic and therefore, it has given priority to segment \( A_1 \) which has a lower volume of traffic. Also, segments \( A_4 \) and \( A_5 \) in which the frequency of accidents with the same cause and the volume of through traffic have been considered equal, from the BAC Model, segment \( A_4 \) is given priority because of its higher degree of severity.

It should be borne in mind that giving priority to a road segment depends on accident frequency, accident cause, degree of accident severity and the volume of traffic all of which have been taken into account in this model simultaneously.

Therefore, as it can be seen from Table 2, there is a significant difference between the BAC Model and other models in such a way that, a segment which was ranked as the last in other prioritizing models was now ranked as the first in the BAC Model. This variation shows the structural difference between these models.

6. Conclusions

Since the main objective of prioritizing high crash road segments is to assign a budget for eliminating their high accident-proneness, thus it is important to consider the main cause of accidents to prioritize them. Since current prioritizing models do not take accident cause into account, for this reason they are not reliable models for prioritizing. Therefore, viewing the issue from a different perspective, this paper proposes the BAC Model, which can take into account factors of accident frequency, accident severity, accident cause, and traffic volume when prioritizing high crash road segments. It should be noted that, accident frequency with a specific severity cannot determine by itself the high accident-proneness of a segment, and this high accident-proneness is better determined by accident frequency from a cause and with a specific severity in a segment.

From earlier discussions in this paper, due to structural differences, there are significance differences in the results of the BAC Model and those of currently used models. The BAC Model will considerably increase the precision and efficiency of the prioritizing the high crash
road segments. Some of the advantages of the BAC Model are:

- Categorizing accident statistics based on their cause of occurrence,
- Giving priority to the segments with the same-type of accidents based on their cause of occurrence,
- Suggesting appropriate strategies with regards to the causes of the accidents,
- Taking into account the multi-dimensional issue of the accident phenomenon and applying different parameters in the model simultaneously,
- The comprehensiveness of the prioritization model (BAC Model) with regards to the accident cause.

REFERENCES


Mahmoodi Moazzam, A., 2002. Investigating the Parameters Contributing to Decreasing the Accident Frequency in High Crash Segments, the Case Study of Kohkilooyeh-Booyerahmad Province of Iran, Thesis, Department of Civil Engineering, Elmosanaa’ University, Tehran-Iran.


Traffic Institute, 1999. Program of Instruction for the Workshop on Identification and Treatment of High Hazard Locations, the Traffic Institute, Northwestern University, Evanston, IL. November.
IDENTIFICATION OF ACCIDENT BLACK SPOTS ON RURAL HIGHWAYS IN INDIA: CASE STUDY OF MAHARASHTRA STATE

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ABSTRACT
Government of Maharashtra state, India has formulated Accident Prevention Committee (APC) in year 1997 for identifying the accident-prone spots on the rural highways in the state and to suggest the suitable remedial measures for reducing the accidents. The committee consists of experts in the field of civil engineering, police, representatives of road users, NGO etc. Committee had inspected about 18027 kilometers of rural highway length in the state and identified 7313 of accident-prone spots (hence after to be designated as ‘Black Spots’). The public works department (PWD) of the state had undertaken the improvement of these identified black spots in stages and improved 5960 numbers of black spots and found that the trend of growing accidents is arrested in the state. The paper will discuss various causes for accidents found in the study, details of counter measures as suggested by the committee. The paper will also discuss how improvement in black spots had been affective in reducing the number of accidents in the state.

1 INTRODUCTION
Maharashtra is one of India’s more advanced States and having a relatively higher density of road network as well as motor vehicles compared to other States and the number of motor vehicles on the road in the State is increasing quite steeply. The State has concentrated on improvement of surfaces of its trunk routes in the past few years resulting in a reduction of travelling time between destinations due to considerable increase in speed of the vehicles plying on these roads. No doubt the State has reaped benefits by way of better industrial development, boost to tourism, economic benefits due to reduced road user costs and better turn around of vehicles, however, the down side of the same was that the numbers of accidents and resultant deaths and injuries were also increasing in sync with the number of motor vehicles. The increase in total motorized vehicles, cars, motor cycles as well as rural population in the state of Maharashtra are shown in Figure 1.
2 APPOINTMENT OF THE COMMITTEE
Recognizing that most of the major roads in the state as well as in the country have been inherited from the days of traffic comprising animals and animal drawn vehicles and therefore having numerous black spots, the PWD of Maharashtra state have appointed ‘Accident Prevention Committee (APC)’ to inspect the accident spots on high density rural corridor of National Highways (NH) and State Highways (SH) in the state and to suggest remedial measures against it under the chairmanship of former Secretary PWD of the state. All the regional PWD Chief Engineers of the state, the Director General (DG) of Police (Traffic), representatives of various other departments/bodies related with road accidents and member of Non Government Organizations (NGO) devoted to the cause of reducing road accidents were nominated as other members of the Committee. The Committee was further reconstituted in year 2007.

3 METHODOLOGY FOR IDENTIFICATION OF BLACK SPOTS
The APC actually inspected about 18027 kilometers length of NH/ SH categories of rural highways in the state and identified 7313 of accident-prone spots in this length. Out of which 6500 number of accident black spots were identified till year 2001 i.e. majority of the black spots were identified during the initial period between years 1997-2001. The general methodology adopted by APC for identification of black spots is summarized as follows:

(i) The local officers of the PWD identified the accident-prone locations in their jurisdiction by observing the accidents data as maintained in local police stations where accidents seem to occur repetitively. These locations were then inspected by APC in its tours. In addition, any other features or locations that APC considered to be dangerous to traffic were also commented on. Detailed observation notes were issued after each tour indicating the possible improvement measures at each such location.
(ii) The Committee classified very dangerous spots needing immediate attention as priority I. A further sub division of the measures was made into immediate, short-term, long-terms and very long-term to enable phasing of work according to availability of funds. General guidelines followed by APC for classification of improvement measures into various categories are given in Table 1.

Table 1 Suggestive Guidelines used for classifying Remedial Measures

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of Remedial Measure</th>
<th>Details included in Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Immediate Measures</td>
<td>Trimming of shrubs and tree branches to improve sight distance, Providing warning boards, Providing speed limit boards, Centre line marking, Edge marking, Providing speed breakers, Painting of parapets and railings, Providing hazard markers, Removal of encroachments, Maintaining shoulders in proper cross slopes.</td>
</tr>
<tr>
<td>2</td>
<td>Short Term Measure</td>
<td>Improvement of junction, Providing precaution boards at junctions, Filling of shoulders, Providing delineators, Providing or extending raling parapet of bridges, Flaring of the parapet walls, Providing bus-bays, Providing extra widening for curves, Removal of humps and jumps, Providing paved shoulders, Widening of road at summit and valleys, Widening of Cross Drainage works, Improving superelevation.</td>
</tr>
<tr>
<td>3</td>
<td>Long Term Measures</td>
<td>Providing dividers, Widening of bridges upto 30m length, Providing superelevation to roads on large scale, Providing widening to road, Providing railing to junction and villages, Improvement to vertical curves</td>
</tr>
<tr>
<td>4</td>
<td>Very long Term Measures</td>
<td>Realignment of road, Regarding of the road, Providing grade separator, Strengthening of road, Widening of major bridges</td>
</tr>
</tbody>
</table>

(iii) Since APC comprises of NGOs as well as Government Officials, the reports of the committee have better credibility both with the Government machinery as well as in the general public. Many a time when there was resistance by the local villagers regarding some measure, the presence of the NGOs had helped lot. They had talk with the local villagers more easily and persuade them to agree to the suggested measures. In one village the highway had a totally blind corner because of a fairly large temple situated right at the corner very close to the road carriageway. The villagers had resisted all efforts by the local PWD officials to shift the temple. However, during the visit of APC to the site, the representatives of the NGOs were able to persuade the local people to permit certain major alterations in the temple, which could clear the vision at the corner.

(iv) Normally if an hour was required to travel on a length of road, the Committee’s inspection had taken as long as 5-6 hours to travel the same length. Attempt was to try to elicit suggestions from the junior-most person in hierarchy before coming to any conclusion thus training the PWD staff into thinking about road safety. This appears to have succeeded to a large extent.
4 DETAILS OF TYPICAL ACCIDENT PRONE SPOTS

After inspecting thousands of kilometers of roads, the Committee had identified following typical locations or situations where accidents occurred repeatedly. However, most of the roads in the state are inherited from ancient times when the mode of transport was on foot, animal backs or in animal drawn carriages. The road geometry and other features are therefore not always the most ideal. The list as given below is not exhaustive, but is indicative.

(i) Village and its water source separated by a highway
At several locations villagers get their water supply from tube well, stand post or reservoir situated across the road from their dwellings. At one location, where 6 to 8 people were dying annually while crossing the highway to access the 350 ft deep bore well. A local villager was bitterly critical of Government because one bore well on the village side of the highway had been abandoned at a depth of 150 feet as unsuccessful when it failed to tap water.

(ii) Narrow bridge
Many of the roads have been widened to have 5.5m wide or 7m wide black-topped carriageway of excellent riding quality. However, in many cases the bridges are so too narrow i.e. about 5 to 6m wide. Vehicles approaching such a bridge at high speed from opposite sides many a times fail to resolve the issue of precedence and crash into each other. Even if the bridges and culverts are 7.5m wide, when fast vehicles approach each other from opposite sides of the bridge at high speed it becomes tricky to pass safely through the 7.5m widths. This situation further aggravates when the road slopes down towards such a bridge from both sides. In fact this is the case at many locations because in the earlier days the deck level of the bridge was solely governed by the hydraulic considerations without any geometrical considerations due to economic measures.

(iii) A right turn of road on a down slope
Generally on such turns the outside shoulder has the usual camber so that the shoulder slopes towards the edge of the formation from the super elevated edge of the blacktopped surface. In fact, in many cases that shoulder is much lower than the blacktopped surface. Vehicles travelling down the slope are generally moving at some speed. If another vehicle approaches the spot at the same time from the opposite side, then the vehicles are forced to move to the edge of the pavement. The outer wheels have to go on the shoulders. At night due to the glare of the headlights of the opposite vehicle, this is more likely to happen. The vehicle turning right at such a location has in effect a negative super elevation. Such locations on busier roads are invariably accident locations.

(iv) Small subsidiary road meeting the main highway in a steep slope
When the slope of the subsidiary road ends almost at the edge of the carriage-way of the main road, the vehicles coming along the subsidiary road and wanting to join the main highway have no space to come to a dead stop before joining the main road. Most of the drivers lack the skill to stop their vehicles on a steep slope and wait for an opening in the traffic on the main road. They usually come at speed and join the main road in a single unbroken motion. The likelihood of an accident at such places is very high.

(v) A summit in the road
A summit is in fact a blind vertical curve unless it has been designed properly with sufficient sight distance. Generally this is not the case. At the start of the gradient, heavier vehicles slow down. In no time at all there is a bunching of vehicles behind the heavy vehicles.
Impatient drivers of smaller vehicles in the bunch, quickly start overtaking despite the lack of sufficient sight distance. On many occasions they meet the oncoming vehicle just near the top of the slope and just when they have drawn level with the vehicle being overtaken. If lucky, the passengers escape with violently applied brakes and exchange of a few angry words otherwise resulting into broken headlights, injury and sometimes death.

(vi) Summits followed by a horizontal curve
Here a driver suddenly faces a horizontal curve just after negotiating the blind summit. Sometimes such vehicles will either over turn or will run off the road.

(vii) Absence of guard stones or curve indicator on the curve
The drivers misjudge or entirely miss the location of the curve and run off the road. In one case in an otherwise perfectly good level stretch, the road has a left hand curve but without guard stones on the outside of the curve. To make matters worse, there was one large hoarding quite some distance from the road boundary such as to be visible to vehicles proceeding in both directions. In absence of guard stones the driver of vehicles mistakenly assumes the location of the curve to be much nearer the hoarding. Too late the drivers realise that they were already on the curve even though quite for off from the hoarding. The problem became worse during night.

(viii) Trees by the roadside
Trees appear to be the biggest killers on the rural highways in the state. In the earlier days when most of the journey was on foot or on animal backs or on animal drawn vehicles, shady trees were a boon. Most of the ancient rulers earned blessings from their subjects by planting trees on the roadside but when the same roads were converted into highways and later on widened, the same trees are proving to be killers. When drivers lose control due to various factors including drowsiness, they dash head on against roadside tree, resulting in deaths and injuries. Many times a row of such trees by the roadside prevents and evasive action by drivers in a tight situation such as misjudgment while overtaking. Almost every fifth grievous accident seems to be occurring due to vehicles hitting the roadside trees. Electric and telephone poles standing close to carriageway also pose similar danger.

(ix) Erosion of shoulders due to cart tracks, footpath or cattle crossing
At several places in a stretch where the shoulder was otherwise in a fairly good condition, one finds a small length of the shoulder badly eroded. Sometimes the shoulder was even 30 to 60 cm below the level of the edge of the black-topped carriageway and also the general level of shoulders. This happens where villagers take-off in carts or with their cattle and implements to go to their fields at such places or where a footpath starts from the edge of the black topped carriageway. Such erosion on the side of a curve on the road was found extremely dangerous.

(x) Places of Worship/prayers
Several such places exist quite close to the road, inside the road land even abutting the carriageway. Several superstitious drivers will suddenly stop their vehicles next to such places of worship/prayers. If there is a fast moving vehicle behind then there is every chance of a rear end collision. Even if the following driver manages to veer out safely into the other lane, he risks being hit by a vehicle coming in the opposite direction. There are several such places along the roads and repeated accidents do take place at such locations. Moving the places of worship/prayers away from the road is almost an impossible task in India. If the
officers in charge are tactful and lucky they may be able to do so in a few cases. Creation of sufficient parking space away from the carriageway for the devotees or re-location of the entrance to the place may reduce the probability of accidents in such cases.

(xi) Passenger pickup sheds at the junction
In most cases such sheds are built right at the corner of junction formed by the two roads, thereby blocking the line of sight of the drivers from the main road as well as the subsidiary road resulting into crashes.

(xii) Wayside bus stop without bus bays
Usually bus drivers stop the buses right on the carriageway for discharging or picking up passengers at wayside bus stops. The exit from the buses is at the rear end of bus. On getting down from the bus, the villagers many a time crosses the road behind the bus to reach their destinations. In these situations, they suddenly step right into the way of a vehicle, proceeding in the opposite direction. The problem is more serious in case of two lane road because in that the vehicles in the other lane are proceeding at speed.

(xiii) Amenities separated from their users
At several locations the college and its hostels with playgrounds are situated an opposite sides of the highways. Sometimes amenities like ration shops, schools, hospitals, bus stops, etc. and the population, which they serve, is located on opposite sides of the highways. Needless to say such spots become contributors of accidents when people cross the road at such places.

5 PARTICIPATION OF PEOPLE
The general public responded profusely as soon as suggestions from the people were invited. Several people wrote long letters with their suggestions to the Committee. The Committee compiled the suggestions as given by public and included in its report for action by appropriate departments of state Government. Usually the Committee was apprehensive of the reaction of the people when the Committee suggested cutting of roadside trees. On several occasions, however, the local people themselves suggested cutting of certain trees, which according to them were causes of accidents. In some occasions, local members of the Legislative Assembly had personally welcomed the Committee in their area and had escorted the Committee to the accident spots and sought remedial measures. The representatives of the people had followed up the subject very keenly since beginning. In every session of the Legislature, some questions on the work of the Committee and action of the Government on it’s recommended are received. The Press in the state had also shown general interest in the subject and had published news about the work of the Committee. Some respected senior leaders of all the parties are continuously pressing the Government for implementation of the suggestions as recommended by the Committee.

5 ACTION BY GOVERNMENT
The Government has been earmarking specific funds for carrying out improvement measures as suggested by the Committee each year. The details of road length as inspected by the Committee, number of identified accident black spots, number of black spots as improved by the state and the details of expenditure for improvement of black spots are given in Table 2. Many of the remedial measures as suggested by the Committee have relatively a low cost implication e.g. fixing of guard stones, cutting of tree branches, putting up hazard markers, road marking, etc.
Table 2: Details of Accident Black spots and Improvement Work by Government (till date 31/03/2009)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Details</th>
<th>Road Category Inspected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>National Highways</td>
</tr>
<tr>
<td>1</td>
<td>Road length in kilometers as inspected by APC</td>
<td>3461</td>
</tr>
<tr>
<td>2</td>
<td>Number of Accident prone spots as identified by APC</td>
<td>1595</td>
</tr>
<tr>
<td></td>
<td>Number of Accident prone spots as identified by APC (till date 31/05/2001)</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>Number of Accident prone spots improved by PWD of the state</td>
<td>1285</td>
</tr>
<tr>
<td></td>
<td>Number of Accident prone spots improved by PWD of the state (till date 31/05/2001)</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>Up-to-date expenditure incurred by state for improvement of Accident prone spots (million dollars)</td>
<td>1373</td>
</tr>
</tbody>
</table>

6 EVALUATION AFTER POST IMPROVEMENT OF ACCIDENT SPOTS

When the immediate and short term measures works as recommended by APC were carried out at the accident black spot locations during the initial period between years 1997-2001, it showed a palpable relief to the traffic in rural part of the state. At several locations the accidents have been eliminated or have reduced to a considerable extent. The details of various accident statistics as compiled by the police department of the state from year 1997 to 2008 are shown in Figure 2. Similarly, two types of road safety indicators i.e. fatalities (or injuries) per number of habitants and fatalities (or injuries) per number of motor vehicles in the state have been worked out for the years between 1997 to 2008 and the details of which are shown in Figure 3 and 4.
Figure 2: Year-wise variation of Accident details

Figure 3: Year-wise variation of Fatalities (or injuries) per 100,000 number Habitants
Figure 4: Year-wise variation of Fatalities (or injuries) per number of Motor Vehicles

Following observations can be made based upon the results as shown in Figures 2, 3 and 4:

(i) From Figure 2 it can be concluded that there is reduction in total number of accidents, number of fatal accidents and number of fatal plus all injuries in the state between the periods of year 1997 to 2002. The possible cause for this may be the effective implementation of improvement measures at accident black spot locations in this period as suggested by APC.

(ii) Since year 2004, there is again increasing trend in all types of accidents, the possible cause for this trend may be the shifting of accident black spots at other locations after curing of earlier black spots as identified by APC.

(iii) By observing the year wise variation in road safety indicator “Fatalities (or injuries) per 100,000 number of habitants” as shown in Figure 3, it can be concluded that there is definite improvement in this indicator in the state between the periods of year 1997 to 2002. The possible cause for this may be the effective implementation of improvement measures at accident black spot locations in this period as suggested by APC. Since year 2004, there is again increasing trend in this indicator and the possible cause for this trend may be the shifting of accident black spots at other locations after curing of earlier black spots as identified by APC.

(iv) By observing the year wise variation in road safety indicator “Fatalities (or injuries) per number of motor vehicles” (excluding motor cycles) as shown in Figure 4, it can be concluded that there is continuous increase in value of this indicator in spite of implementation of improvement measures at accident black spot locations in the state, hence there is a need of promoting other non-engineering measures in order to improve road safety in the state.
7 CONCLUSION
The reduction of number of road accidents, injuries and deaths after road improvement work as per APC suggestions, is found quite encouraging in the initial period between years 1997 to 2002 in the state. It can be conceded that there would be some other contributory factors like awareness of the drivers and the general public or some other factors contributing to the reduction. However, after year 2003, there is again increasing trend in accident rates in the state, the possible reason for the same may be the shifting of accident black spots at other locations after curing of earlier black spots as identified by APC. Hence, there seems the need for carrying out fresh accident black spot identification study on rural highways in the state, in view of the changed scenario. Also there is a need of promoting other non-engineering measures such as serious attention of licensing authorities towards proper training to drivers, review of licenses, strict enforcement of law, etc.

REFERENCES

Analysis of Risk Factors for Rear-end Collisions by Using Drive-recorder Data

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ABSTRACT
In order to reduce traffic accidents, it is necessary to clarify how drivers cause accidents. Based on drivers’ reports after accidents, it is well known that most accidents are caused by human errors. However, there is little data available on drivers’ operation and traffic situation at the time of accidents. The authors have been developing a video-based drive-recorder to enable accidents to be scientifically analyzed. The recorder is mounted on a vehicle and records time-history data of the driver’s operation and vehicle acceleration at the moment of an accident and/or near-miss incident. Field tests for collecting accident and incident data have been conducted in a suburb of Tokyo, Japan since 2006, capturing data for 24 accidents and 879 incidents by 10 taxi vehicles and 29 drivers.

This paper describes the risk factors for rear-end accidents and near-miss incidents based on data collected by the drive-recorders. First, the time headway (THW) of the incidents is estimated by using the recorder data. Then, the driver’s responsibility in each case is classified into several error types and the relationship with driver’s braking behavior is analyzed. The results show that there is a risk of a rear-end collision when THW is less than 4.2 seconds. Inattention and following a car too closely affect the risk of a rear-end collision. In addition, an effective safety technology to prevent such accidents is discussed.

1 INTRODUCTION
Police statistics show that 5,587 people were killed on roads in fiscal 2008 in Japan. Road fatalities in Japan have been decreasing as a result of crash safety technology and emergency medical services after crashes. However, there were still 766,147 road accidents, with 950,659 people injured.

To reduce traffic accidents and casualties, it is necessary to investigate the causes of accidents. Based on drivers’ reports after accidents, it is well known that most accidents are caused by human error. However, it is impossible to identify the accident causes objectively. In addition, in contrast to the classical approach, there is little scientific data available concerning the relation between drivers’ behavior and traffic situation at the time of accidents. Some previous studies analyzed the relation between accident risk and human factors using some theoretical models [e.g., Summala, H. (1996), Wagenaar, W.A., et al. (1990)].

The authors have been developing a video-based drive-recorder for scientifically analyzing accidents [Tominaga et al., (2005), (2006)]. The recorder is mounted on a vehicle and records video images, driver’s operation data, and vehicle velocity and acceleration data at the
moment of an accident or near-miss incident. Field tests using the recorder to collect accident and incident data have been conducted in a suburb of Tokyo.

In this paper, risk factors for rear-end accidents and incidents are analyzed by using drive-recorder data. The time headway of rear-end incidents is estimated, drivers’ factors involved in the situation are classified into several types of human error, and their relationship with driver’s braking behavior is analyzed. In addition, an effective safety technology to prevent accidents is discussed.

2 DRIVE-RECORDER

Figure 1 shows the drive-recorder we developed for the present study. The recorder system consists of several sensing devices: 2-channel CCD cameras, acceleration sensor, gyro sensor, GPS sensor and memory for storing recorded data.

The drive-recorder is installed on the test vehicle as shown in Figure 2. The CCD camera for recording the front view is mounted on the front window and another camera for recording the driver’s expression and behavior is mounted on the dash-board. Acceleration and gyro sensors are installed near the center of gravity of the vehicle. The main unit also has wires for the vehicle speed pulse signal, braking signal, turn signal, and vehicle position data from GPS.

Table 1 shows the items of data that are recorded and the sampling frequency of the recorder. The recorded items are: 2-channel video (outside view from the front window and inside view of the driver’s face and steering wheel handling), 3-axis acceleration and angular velocity, vehicle velocity, braking signal, turn signals and vehicle position from GPS. Data is sampled at the frequency of 30 fps for video recording, 100 Hz for the accelerometer and angular velocity sensors, 10 Hz for braking operation and turn signal data, and 1 Hz for vehicle position data from GPS.

Data recording by the recorder is triggered based on a data recording algorithm. This algorithm was designed using real-time monitoring of vehicle acceleration and angular velocity. The acceleration $a_{xy}$ of the vehicle is calculated from the longitudinal acceleration $a_x$ and lateral acceleration $a_y$ on-line by the equation,

$$a_{xy} = \sqrt{\left(\frac{a_x}{G_x}\right)^2 + \left(\frac{a_y}{G_y}\right)^2} \geq 1.0$$

where, $G_x$ and $G_y$ are threshold values of longitudinal acceleration and lateral acceleration, respectively. These threshold values represent the degree of crash impact of an accident or sudden braking for a near-crash incident. In this study, $G_x$ and $G_y$ were set at 0.4 m/s$^2$. The data recording period is from 10 seconds before to 5 seconds after an accident or incident.

The graphical user interface (GUI) for recorder data analysis is shown in Figure 3. The GUI has three parts. The first one is information on the accident or near-miss incident. This part shows the time when the accident or near-miss occurred, vehicle identification number (VIN) and video image of the front view and driver’s behavior. The second part shows time history data of the acceleration and angular velocity of the x, y, and z axes, vehicle velocity, braking signal and turn signal data. The third part shows information about the driver, including name, age, gender, height and weight, which is registered by the driver in advance.
Table 1. Data items of drive-recorder

<table>
<thead>
<tr>
<th>Data items</th>
<th>Range</th>
<th>Sampling frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle acceleration</td>
<td>500 m/s²</td>
<td>100Hz</td>
</tr>
<tr>
<td>(x, y, z axis) for accident</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Acceleration</td>
<td>2 m/s²</td>
<td>100Hz</td>
</tr>
<tr>
<td>(x, y axis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle angular velocity</td>
<td>300 deg/s</td>
<td>100Hz</td>
</tr>
<tr>
<td>(x, y, z axis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2ch-video image recording</td>
<td>640 x 480 dots</td>
<td>30fps</td>
</tr>
<tr>
<td>(Frontal view and inside view)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle speed</td>
<td>Speed pluse</td>
<td>10Hz</td>
</tr>
<tr>
<td>Brake signal on/off</td>
<td>on/off</td>
<td>10Hz</td>
</tr>
<tr>
<td>Turn signal (Left and Right)</td>
<td>on/off</td>
<td>10Hz</td>
</tr>
<tr>
<td>Vehicle position data</td>
<td></td>
<td>1Hz</td>
</tr>
<tr>
<td>(from GPS)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Drive-recorder

Figure 2. Installation of drive-recorder

Figure 3. GUI for drive-recorder data analysis
3 COLLECTED DATA ON REAL TRAFFIC

Field tests for collecting accident and incident data on actual roads have been conducted in a suburb of Tokyo since April 2006. The drive-recorder has been installed in a total of 10 taxi vehicles, which are driven by 29 professional drivers (two drivers in the daytime and one at night for each taxi). The taxi drivers in this field test area drive about 200 km per day.

Data on a total of 24 accidents and 879 incidents have been collected during the field test period; no accidents involved injury.

In this study, the definition of traffic accidents and incidents is:

- Accident: Any contact between the vehicle with drive-recorder installed and another vehicle, fixed object, moped rider, cyclist or pedestrian
- Incident: Sudden braking and/or rapid steering maneuver to avoid a crash without resulting in an accident

All of the accident and incident data were classified by type of accident or incident according to the categories of police accident statistics. An analyst reconstructed the accident and incident data by using the recorded front view video images, and then manually classified the type of accident or incident.

Table 2 shows the number of collected data by accident and incident type. As for accident data, data for two cases of rear-end, three cases of turning left and two cases of head-on were recorded by the drive-recorder. Accidents/incidents classified in the “others” category include hitting fixed objects and animals, etc. As for incident data, rear-end and crossing incidents accounted for approximately 50% of all incident data. Especially, rear-end incidents were the most common type, followed by crossing incidents, which include car/car, car/cyclist and car/pedestrian. Right turn and left turn incidents were about 12% and 11%, respectively.

<table>
<thead>
<tr>
<th>Type of Accident</th>
<th>Number</th>
<th>Percentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>Crossing</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Right turn</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Left turn</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>Head-on</td>
<td>2</td>
<td>8.3</td>
</tr>
<tr>
<td>Others</td>
<td>17</td>
<td>70.8</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Number</th>
<th>Percentage(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end</td>
<td>212</td>
<td>24.1</td>
</tr>
<tr>
<td>Crossing</td>
<td>201</td>
<td>22.9</td>
</tr>
<tr>
<td>Right turn</td>
<td>109</td>
<td>12.4</td>
</tr>
<tr>
<td>Left turn</td>
<td>97</td>
<td>11.0</td>
</tr>
<tr>
<td>Head-on</td>
<td>77</td>
<td>8.8</td>
</tr>
<tr>
<td>Others</td>
<td>183</td>
<td>20.8</td>
</tr>
<tr>
<td>Total</td>
<td>879</td>
<td>100</td>
</tr>
</tbody>
</table>

Others: fixed object, animal, etc

In the next section, risk factors involved in rear-end incidents were analyzed, with a view to preventing such incidents. Especially, the relation between the effect of human errors and the traffic situation classified by recorded video images and incident occurrence was analyzed.

4 ANALYSIS
4.1 Time headway

From the front video image and vehicle velocity data measured by the drive-recorder, the sequence of rear-end incidents was reconstructed. Figure 4 shows a typical pattern of rear-end incidents, which contains three phases.
• Phase 1: Following of target car
• Phase 2: Human error
• Phase 3: Sudden braking

![Diagram of car-following sequence](image)

**Figure 4. Sequence of rear-end incident**

Time headway (THW) at the time of becoming aware of an incident was estimated from the drive-recorder data. THW is an index of the risk in a car-following situation, and is calculated by,

\[
THW = \frac{\Delta X}{V} \text{ (sec)}
\]

Eq. 2

where, \(V\) is velocity of subject vehicle and \(\Delta X\) is relative distance between subject vehicle and target vehicle. The value of \(V\) was obtained from the vehicle velocity pulse data of the recorder. \(\Delta X\) was estimated by analyzing the recorded video images.

Figure 5 shows a scatter plot of vehicle velocity \(V\) and relative distance \(\Delta X\) of the collected rear-incident data. The figure shows that rear-end incidents tend to occur in situations when THW is less than 4.2 sec. In other words, there is no risk of a rear-end incident or accident when THW is more than 4.2 sec.

![Scatter plot of vehicle velocity V and ΔX](image)

**Figure 5. Scatter plot of vehicle velocity V and ΔX**
4.2 Human errors
In order to explore the risk factors associated with incidents, human errors by the principal drivers who caused the incidents were analyzed. Video images recorded by the CCD of the driver’s behavior were analyzed for collected incident data. The results showed that human errors could be classified into four types as shown in Table 3.

Table 3. Classification of human errors

<table>
<thead>
<tr>
<th>Classification</th>
<th>Risk factors</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delays in recognition</td>
<td>Forward inattention</td>
<td>Type 1</td>
</tr>
<tr>
<td>Driver's distraction, operating navigation system</td>
<td>Type 2</td>
<td></td>
</tr>
<tr>
<td>Blind corner</td>
<td></td>
<td>Type 3</td>
</tr>
<tr>
<td>Miss-judgement</td>
<td>Follow too closely and sudden braking of target car</td>
<td>Type 4</td>
</tr>
</tbody>
</table>

Type 1 is inattention and not looking around the car. Type 2 is driver’s distraction due to performing navigation, audio and air-conditioning operations. Type 3 is blind corners. These errors are defined as delays in recognition. On the other hand, Type 4 is classified misjudgment caused by following too closely and sudden braking by the target car.

Table 4 shows the result of classifying human errors by incident type. Type 1 and Type 2 were classified as “Right turn” and “Left turn” incidents more frequently. Type 3 was classified as “Crossing” and Type 4 was classified as “Rear-end” incidents more frequently. This result indicates that there is a relation between human error type and incident type. As for rear-end incidents, 25% of cases were Type 4, and Type 2 was the next highest category of human errors.

Table 4. Classification of human errors by incident type

<table>
<thead>
<tr>
<th>Type of Incident</th>
<th>Type_1</th>
<th>Type_2</th>
<th>Type_3</th>
<th>Type_4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rear-end</td>
<td>1</td>
<td>37</td>
<td>0</td>
<td>174</td>
</tr>
<tr>
<td></td>
<td>(0.1%)</td>
<td>(5.3%)</td>
<td>(0%)</td>
<td>(25%)</td>
</tr>
<tr>
<td>Crossing</td>
<td>7</td>
<td>2</td>
<td>191</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(1.0%)</td>
<td>(0.3%)</td>
<td>(27.4%)</td>
<td>(0.1%)</td>
</tr>
<tr>
<td>Right turn</td>
<td>81</td>
<td>1</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(11.6%)</td>
<td>(0.1%)</td>
<td>(3.9%)</td>
<td>(0%)</td>
</tr>
<tr>
<td>Left turn</td>
<td>82</td>
<td>1</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(11.8%)</td>
<td>(0.1%)</td>
<td>(2.0%)</td>
<td>(0%)</td>
</tr>
<tr>
<td>Head-on</td>
<td>2</td>
<td>0</td>
<td>49</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>(0.3%)</td>
<td>(0%)</td>
<td>(7.0%)</td>
<td>(3.7%)</td>
</tr>
<tr>
<td>Total</td>
<td>173</td>
<td>41</td>
<td>281</td>
<td>201</td>
</tr>
<tr>
<td></td>
<td>(24.1%)</td>
<td>(5.9%)</td>
<td>(40.4%)</td>
<td>(28.9%)</td>
</tr>
</tbody>
</table>
Figure 6 shows the distribution of THW by human error type for rear-end incidents. It can be seen that Type 4 frequently occurs when THW is less than 2.0 sec. Type 2 occurs most frequently when THW is 1.0 to 2.0 sec. The results indicate that there is a lower risk of rear-end incidents when THW is more than 2.0 sec.

![Figure 6. Distribution of THW by human error type for rear-end incidents](image)

4.3 Driver’s behavior and reaction time

Figure 7 shows the detailed data obtained from the drive-recorder classified according to driver maneuver based on the camera images, vehicle motion sensors and traffic environment with map matching. Figure 7 shows an example of data for Type 2 human error at the moment of a rear-end incident.

As for Type 2 human error incidents, inattention while driving and eye glance behavior were analyzed from the video images captured by the inside-view camera. Figures 7 (a) and (b) show the sequence of the driver’s behavior and classification of each response time for eye glance behavior, where,

- $t_0$: Start to glance
- $t_h$: Hazard occurs (target vehicle stops suddenly)
- $t_1$: Perception of hazard
- $t_2$: Recognize urgent situation
- $t_3$: Start to brake

The time from $t_1$ to $t_3$ in the present study was defined as the perception-brake reaction time, and was estimated for each rear-end incident. Figure 8 shows the distribution of brake reaction time for Type 2 rear-end incidents. The results show that the perception-brake reaction times varied between 0.2 sec and 0.9 sec, and tended to range from 0.5 sec to 0.6 sec. The mean perception-brake reaction time was 0.57 sec. Compared to a previous study [Green, M. (2000)], the present results suggest that perception-brake reaction time in an urgent situation is faster than that estimated by simulators and road experiments.
Figure 7. Time history analysis of driver behavior for rear-end incidents

Figure 8. Distribution of perception-brake reaction time for Type 2 rear-end incidents.
5. SUMMARY AND CONCLUSION

To reduce traffic accidents, the authors have been developing a drive-recorder for scientifically analyzing accidents and the associated risk factors. The recorder captures the front view and inside view of the vehicle by CCD cameras, as well as measured time history data of vehicle dynamics, driver maneuver and position data from GPS.

Field tests have been conducted since 2006 to collect accident and incident data. Data for 24 accidents and 879 incidents have been collected. Rear-end and crossing incidents account for approximately 50% of all incidents, with rear-end incidents being the most common type.

Risk factors that influence rear-end incidents were examined. THW at the time of becoming aware of an incident was estimated. The results showed that there was no risk of a rear-end incident when THW was more than 4.2 sec. Next, human errors that affected the incident were analyzed. Delays in recognition due to driver’s distraction and mis-judgment when following too closely were the most frequent human errors. The relation between these two errors and THW was analyzed, and it was found that THW and human errors contribute to rear-end incidents.

Our study revealed that drive-recorder data are useful for analyzing the risk factors of accidents and incidents in terms of driver’s behavior. Future studies will examine the risk factors for other types of vehicle accidents involving pedestrians, cyclists, motorcyclists.

ACKNOWLEDGMENT

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REFERENCES


IN-DEPTH INVESTIGATION OF SEVERE AND FATAL ROADWAY CRASHES IN THE EMIRATE OF ABU DHABI-UAE

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Abstract

This paper highlights the details of the in-depth crash investigation research project carried out jointly by the UAE University (Roadway, transportation and Traffic Safety Research Center) and the Health Authority of Abu Dhabi. The paper summarizes the conceptual differences between the conventional police investigation and the underlying in-depth approaches. Reference is made to the world-wide systems adopting similar in-depth assessment of roadway crashes. The procedure of investigation including the site investigation, vehicle inspection and patients' interviews is summarized, with brief description to the inclusion criterion for recruiting cases in the study.

The paper also presents some of the earlier findings of data collections in the first few months of the study. The database capabilities are briefly presented by the analyses of the crash classifications and severities. A sample research question on the relationship among the seatbelt, airbag and sustained injury levels is presented.

INTRODUCTION

In the UAE, the incidence of motor vehicle crashes is becoming a major concern and a leading health threat. In fact, injury sustained in a motor vehicle collision is among the leading causes of death, not to mention the associated socio-economical losses. In a recent study done by the RTTSRC- UAE University to UAE National Transport Authority (NTA), the total cost of injury roadway crashes in UAE was estimated to cause a total of loss of about 21 billion AED annually (adjusted to the actual injuries and fatalities at the year of 2008) (RTTSRC, 2009). The Emirate of Abu Dhabi is one
of the highest in terms of experienced number of injury crashes (about 3000 crashes in 2008 out of 10000 UAE total), with more than 50% of these injury crashes on major arterials and highways. It is roughly estimated that the economical losses due to road crashes in the Emirate of Abu Dhabi (direct and indirect including medial cost, insurance loss, property damage, family income losses, GDP loss, traffic congestion delays) would amount to more than six billions AED annually.

Road traffic crashes occur from a combination of factors related to the components of the system comprising roads, the environment, vehicles and road users, and the way they interact. Some factors contribute to the occurrence of a collision and are therefore part of crash causation. Other factors aggravate the effects of the collision and thus contribute to trauma severity. Identifying the risk factors that contribute to road traffic crashes is important in identifying interventions that can reduce the risks associated with those factors (Mohan et al., 2006).

In the United Arab Emirates (UAE), there is data on crashes in databases maintained by the police, hospitals, insurance agencies and others but in many ways the data has limitations, and only can be used to gain some general insights but not deeply sufficient to make general conclusions on aspects of trends of crashes and to set traffic safety policies or suitable interventions. Police-based crash investigations mainly focus on determining individuals’ ‘legal’ responsibility, in relation to their violations to the traffic regulations, as a focal objective. As such, many ‘primary’ roadway-crash injury-causal factors related to vehicle design, human behaviors, road and traffic safety engineering, natural, cultural and social environments, etc., are somehow overlooked, thereby limiting the scope, breadth and depth in these regards. Moreover, many other ‘secondary’ factors which are known to influence the final outcomes of injury to casualties, following crashes, such as availability, responsiveness and access to emergency medical services (EMS), failure of vehicle safety features (such as airbags), or inappropriate road furniture (such as barriers) are again overlooked leading to a gap in information and knowledge of how effective is the traffic safety system. Limitations also include the amount and type of variables recorded on each crash. It is well established that one of the key prerequisites for a successful road safety program is the collection of high quality information outlining with sufficient depth the root causes and factors contributing to road traffic crashes.

During the recent years, in-depth studies of road traffic crashes have been carried out in several countries and by using various methods. In the Nordic countries, multidisciplinary crash investigation teams in Finland have been studying fatal crashes since 1968. They have covered almost all fatal crashes involving a motor vehicle as well as those with personal injuries from more specific types of crashes. Sweden has used multidisciplinary crash investigation teams on a trial basis in 1976–1978, using a theoretically based behavioral science approach with the importance attached to the pre-crash phase (Larsen, 2004). The same method was used in 1991–1994 by new crash investigation teams, initiated and financed by the Swedish National Road Administration. In Denmark, a multidisciplinary team carried out in-depth analyses for some years in the 1960s, focusing on the pre-crash phase. In-depth crash investigation method is paramount, as witnessed in developed countries such as Australia (ANCIS, CARS), UK (SafetyNet), Germany (GIDAS), and the US (NASS, FARS), in providing enhanced information about the multiple causes and managerial aspects of major road traffic crashes and is known to help leading to a number of new
road safety countermeasures. All the above projects were cited by the list of references [4-12].

The RTTSRC- UAE University collaboratively with the Health Authority of Abu Dhabi have developed an in-depth crash investigation program that covers all three regions of Abu Dhabi Emirate including Abu Dhabi city (Island/Middle Region), Al Ain (Eastern Region) and the Western Region (Al Gharbia). The aim of this program is to understand the true causes and mechanisms which lead to severe injuries and fatalities in road traffic crashes. The in-depth crash investigation approach entails the development of a database that captures detailed information describing driver characteristics and behavior, vehicle dynamics, vehicle-roadway interaction, roadway design features, and environmental issues related to vehicle crashes. Such a database permits direct investigation of the crash causing factors, rather than indirect analysis of correlation between limited road and crash variables. This constitutes a giant step towards identifying the true causal factors of motor vehicle injuries and fatalities on the Emirate’s highways, providing better understanding of motor vehicle crashes.

THE IN-DEPTH CRASH INVESTIGATION PROCESS

The Abu Dhabi Comprehensive In-depth Crash Investigation initiative has a target to investigate a fixed representative sample (200 crashes per year) of all fatal and severe road traffic crashes, which take place in Abu Dhabi Emirate. The analysis of the database, when completed, will serve as a reliable evidence-based source of information for understanding and therefore, developing and improving road safety standards and procedures in Abu Dhabi and the UAE in general; an effort which will help reducing roadway crashes, injuries, disabilities, deaths and related health care costs. The study will also constitute a significant tool to understand, develop and improve the level of health education and road safety awareness among the population, as well as monitoring, measuring and evaluating the effectiveness of road safety interventions adopted in the UAE. The objectives of this program are:

- To determine the type and severity of impacts to passenger and non-passenger vehicles in which the road users have been either hospitalized or fatally injured in Abu Dhabi, UAE;
- To evaluate the real-world performance of the structure and existing safety features of all passenger vehicles in Abu Dhabi;
- To correlate occupant injury outcomes with the above;
- To identify causes of road traffic crash injury;
- To identify factors that increase or decrease risk in motor vehicle crashes in Abu Dhabi Emirate and to envisage factors that might be modifiable through interventions;

The in-depth crash investigation approach entails the assessment of vehicles involved in the crash, the crash site, interviews with patients and/or crash witnesses, in addition to accurate medical assessment of the sustained injuries (according to hospital medical records and patient interviews). The study team secured all necessary approvals from Abu Dhabi Police (ADP), Ministry of Interior (MOI), Health Authority - Abu Dhabi (HAAD), Abu Dhabi Health Services Company (SEHA), as well as the Ethics Committees of Hospitals in the Emirate receiving RTA casualties.
The investigation approach is retrospective in nature to ensure the quality of collected data, maintaining confidentiality, and maximizing the benefits of using crash data. An extensive on-line database is developed for this purpose. The database comprises more than 800 vehicle fields, 200 site fields, 150 patient fields, and more than 100 potential contributing factors. The database is systematically audited and maintained. The methodology of data collection enables multi-variant statistical analysis, cross classification of multi-variables including injury outcomes, and even sophisticated simulation-based animated accident re-construction. The in-depth crash investigation process is summarized below:

**Crash Information:**
- The process is of a retrospective nature; i.e. can be investigated on-spot or when crash scene is cleaned based on evidence from site, vehicle and patients interviews. The Research Coordinator gathers information (patients, vehicles and site) regarding the crash from the underlying police departments on a frequent basis. If the crash meets some inclusion criteria (that can be adopted to fit the project needs), the research engineers are informed on the crash vehicle(s) and site, and the research nurse proceed to interview and collect data from the patient(s) and hospitals.
- The Research Coordinator also collects the police report form of the police.
- The availability of the crashed vehicle(s) is ensured by the Research Coordinator from the police vehicle yard.

**Vehicle Inspection:**
- The vehicle is investigated and measured comprehensively by the Vehicle Safety Research Engineers according to the Vehicle Inspection Form (more than 800 fields to be filled, checking all vehicle elements including brakes, lights, seatbelts, airbags, tire conditions, oil leaks, intrusions, dimensions of vehicle impacts, etc).
- Comprehensive digital photographs of the vehicle are taken by Research Engineers to analyze the injury and crash scenario.
- The Research Engineers also calculate the term “delta v” (the speed change that the vehicle experiences as a result of the crash), Equivalent Barrier Speed and Energy using CRASH 3 reconstruction software.
- All collected information is coded into SPSS database.
- Recently, RTTSRC has been undertaking a major effort to provide a linkage of in-depth database with a GIS mapping and database inquiry system. The system is a Google-based and internet-based system that enables data access and GIS analysis; essential elements for the hotspot analysis and safety strategy review.

**Site Inspection:**
- The crash site is identified by the GPS data collected from site. The basic information (description and drawing of the crash) from the police report are also collected.
- After identification of the crash site, the Highway Safety Engineers visits the crash site.
- Road and road environmental characteristics such as speed limits, line markings, traffic signs and signals, tyre marks and topology including for
instance curvature degrees, sight distance, fencing and barrier conditions and dimensions are recorded by the engineers and also a plan of the crash site is developed and the crash site inspection form is also filled up.

- Evidence from crash site and measurements of infrastructure impact deformation is used in estimating the energy of the impacts and the retrospective estimation of the delta v value.

**Patient Interview:**

- The Research Nurse approaches the patient(s) after getting the information about a crash from the research coordinator (this only applies when permission is granted and a consent form is signed by the injured person). Consent may be sought also from a parent, legal guardian or next of kin where the participant is under-aged participants, or if his/her medical condition does not permit correspondence with the research nurse.

- A 20 minute structured interview is conducted with participants which involves the participants answering questions relating to the human, vehicle and road environment factors, both pre- and post-crash.

- The participant’s medical records are recorded and all verified injuries documented and coded in accordance with the Abbreviated Injury Scale (AIS) (Association for the Advancement of Automotive Medicine, 1998). The Maximum Abbreviated Injury Score (MAIS) and Injury Severity Score (ISS) are also determined in office afterwards. AIS, MAIS, and ISS are the technically sound scales to quantify the severity of the crash. It is worth noting that the currently used method by the police is quite subjective and based on the classification of the ER physician, and was found to incur occasional errors. The use of AIS, MAIS, and ISS are recognized world-wide as the most accurate methods for injury classification. These scores can be related to the delta v and the energy of impact to identify the crashes of not particularly high energy impact, yet severe injuries. These crashes may be indicators of unacceptable vehicle safety features or inefficient EMS and medical services.

- It is worth mentioning that being done by an academic institute (RTTSRC-UAE University) assures the participants the confidentiality of information they disseminate to the research nurse. The in-depth crash investigation is designed to be carried out by a non-biased primarily research-based institute, and as such it receives a high response rate by the interviewed patients. More than 95% of all the considered fatality and severe injury crashes were actually consented by participants. This indicates the level of trust in such system by participants. This has resulted in a rigorous system of high quality detailed information and high degree of confidence.

**Contributing Factor(s):**

- Each crash is audited by all participating team members; the vehicle safety engineer, the site inspection engineer, the coordinator, and the research nurse. In addition, the team leader (the safety manager) reviews and audits the cases for quality control.

- The case is prepared including a Participant Interview Form, a Vehicle and Site Inspection Forms and the Police report. The auditing sessions are also intended to resolve the contact sources for each injury, which are coded using both Injury Causation Codes (ICC) and National Accident Sampling Codes.
(NASS) systems. Furthermore, all crash and injury contributing factors are determined using a ‘best evidence synthesis’ approach.

- The Traffic Safety Research Engineer prepares a summary sheet containing all pertinent features of the case and checks the entire case for consistency and identifies and corrects any errors.
- A sample of a summary sheet investigated is shown in Figure 1.

![Figure 1: Sample of the Summary Sheet of a Severe Injury Crash](image)

**Database Coding and Analysis:**
- Completed cases are rechecked and reviewed while coding the paper forms via the SPSS database (version 17.0), which is used for statistical analysis and
identifying the prominent causal factors and suitable preventive measures to report to the appropriate authority.

- In the analysis of the database, a technically sound approach is used entailing tests of hypothesis, cross classification, multi-variant analysis and regressions.

**Inclusion Criteria:**
- At least one driver/rider/passenger/pedestrian was taken to and admitted by hospital for at least one night and reported by hospital as "severe" injury, or at least one driver/rider/passenger/pedestrian was killed as a result of a roadway crash;
- Only crashes in which at least one driver/rider/passenger/pedestrian or legal representative (e.g. next of kin/parents) is willing to be interviewed and has signed a Consent Form;
- In cases where the participant is not the vehicle owner, consent must be supplied both by the vehicle owner and the casualty(s) involved in the crash;

**Exclusion Criterion:**
- Casualties who do not grant written consent, or consent is not granted by their legal representative;

### DATA COLLECTION AND PRELIMINARY ANALYSES

The study area encompasses the Abu Dhabi Emirate of United Arab Emirates, focusing on fatal and serious road traffic crashes of Abu Dhabi City, Al Ain (Eastern Region) and Western region (Tarif, Madinat Zayed). The socio-economic characteristics of these regions are Urban (Major arterial and other city road) and Rural (Motorway and other access road). The difference in road types and socio-economic characteristics of these areas will be considered during data analysis. The patient interview for this study involved seven hospitals (2 in Al Ain region and 3 in Abu Dhabi, and two in Western Region). All fatal and serious road traffic crashes are recruited/excluded in/from the study if they meet the above mentioned inclusion criteria.

### Table 2: Summary of database

<table>
<thead>
<tr>
<th>Region</th>
<th>Investigation Cases</th>
<th>Investigation Crashes</th>
<th>Analysis Cases</th>
<th>Analysis Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu Dhabi</td>
<td>63</td>
<td>49</td>
<td>56</td>
<td>48</td>
</tr>
<tr>
<td>Western Region</td>
<td>21</td>
<td>10</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td>(Tarif, Madinat Zayed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Ain</td>
<td>69</td>
<td>60</td>
<td>68</td>
<td>60</td>
</tr>
</tbody>
</table>

* Cases/crashes finalized and considered for statistical analysis in this paper. Some investigated cases are still pending some information (e.g. patient is still hospitalized; site location is not confirmed)

In the first ten months of the study, a total of 154 cases (126 crashes) were investigated by the RTTSRC-UAEU research team. Table 2 provides an updated summary of the study progress. Figure 2 illustrates the maximum Abbreviated Injury Scales (AIS) (index ranging between 1 to 6) for the investigated cases. All data were collected to randomly cover casualties in the Abu Dhabi Emirate. The in-depth crash investigation approach enables accurate medical classification of injury outcomes.
The in-depth crash investigation approach enables accurate assessment of vehicle as well as pedestrian crashes. The in-depth crash investigation approach enables accurate classification of the crash type (using the universal DCA coding methodology). Table 3 shows the DCA distribution.

Figure 2: Frequency Distribution of AIS

Table 3: Definitions for Classifying Accidents (DCA) distribution

<table>
<thead>
<tr>
<th>DCA</th>
<th>Highway Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rural</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>19.2%</td>
</tr>
<tr>
<td>Intersections only</td>
<td>3.8%</td>
</tr>
<tr>
<td>Vehicles from opposing direction</td>
<td>11.5%</td>
</tr>
<tr>
<td>Vehicles from same direction</td>
<td>28.8%</td>
</tr>
<tr>
<td>Maneuvering</td>
<td>0.0%</td>
</tr>
<tr>
<td>Overtaking</td>
<td>1.9%</td>
</tr>
<tr>
<td>On path</td>
<td>7.7%</td>
</tr>
<tr>
<td>Off path-on straight</td>
<td>21.2%</td>
</tr>
<tr>
<td>Off path-on curve</td>
<td>5.8%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Sample Research Question
A research question is presented herein for illustration of the database capabilities. The question is particularly related to the interaction between the seat belt and air bag deployment in reducing the resulting injuries. The available data is limited; it is not expected that this sample will produce general conclusions.

Relationship between seat belt status and occupant status
The sources of information on the status of seat belt usage (used/non used) include the patient interview and patient injury pattern, vehicle inspection and police report. Table 4 indicates that 52% of drivers’ patients were not using seat belts. 71% of the passenger patients were not using a seat belt. Overall, 69 occupants did not use seat belts (out of 115), representing almost about 60% of the studied cases.

Relationship between seat belt status and severity
Table 5 shows the severity of occupant’s injury and seat belt usage. Strong evidence indicated that seat belts were not used in 66% of fatal injuries, in 49% of serious injuries, and in 61% of moderate injuries. Among all occupants with no seat belt
usage, 45% reported fatalities, 33% reported serious injuries and 22% reported moderate injuries.

Relationship between seat belt status by passenger position
Table 6 indicates the distribution of passenger position by seat belt usage. The total number of passengers included in the analysis is 43, out of whom 17 front seat and 12 back seat passengers did not use seat belt. Only 14 passengers (out of the 43) were confirmed to use seat belt.

Table 4: Distribution of Seat Belt Use Status by Occupant Status

<table>
<thead>
<tr>
<th>Occupant Status</th>
<th>Seat belt</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
<td></td>
</tr>
<tr>
<td>Driver</td>
<td>33 (52%)</td>
<td>31 (48%)</td>
<td>64 (100%)</td>
</tr>
<tr>
<td>Passenger</td>
<td>36 (71%)</td>
<td>15 (29%)</td>
<td>51 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>69 (60%)</td>
<td>46 (40%)</td>
<td>115 (100%)</td>
</tr>
</tbody>
</table>

- Data in bracket represents row percentage

Table 5: Distribution of Injury Severity and Seat Belt Usage

<table>
<thead>
<tr>
<th>Severity</th>
<th>Seat belt</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>14 (61%)</td>
<td>9 (39%)</td>
<td>23 (100%)</td>
</tr>
<tr>
<td>Serious</td>
<td>21 (49%)</td>
<td>22 (51%)</td>
<td>43 (100%)</td>
</tr>
<tr>
<td>Fatal</td>
<td>29 (66%)</td>
<td>15 (34%)</td>
<td>44 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>64 (58%)</td>
<td>46 (42%)</td>
<td>110 (100%)</td>
</tr>
</tbody>
</table>

Table 6: Distribution of seat belt usage and passenger position

<table>
<thead>
<tr>
<th>Passenger Position</th>
<th>Seat belt usage</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
<td></td>
</tr>
<tr>
<td>Front</td>
<td>17 (63%)</td>
<td>10 (37%)</td>
<td>27 (100%)</td>
</tr>
<tr>
<td>Left back</td>
<td>6 (86%)</td>
<td>1 (14%)</td>
<td>7 (100%)</td>
</tr>
<tr>
<td>middle back</td>
<td>3 (100%)</td>
<td>-</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>Right back</td>
<td>3 (50%)</td>
<td>3 (50%)</td>
<td>6 (100%)</td>
</tr>
<tr>
<td>Total</td>
<td>29 (67%)</td>
<td>14 (33%)</td>
<td>43 (100%)</td>
</tr>
</tbody>
</table>

Relationship between seat belt status by abbreviated injury scale of body region
The Abbreviated Injury Scale (AIS) is an anatomically based global scoring system that classifies each injury in various body regions according to its relative importance on a six-point ordinal scale. Using of seat belt and injury severity of body region is reciprocally related. Tables 7A through 7C demonstrate the severity of injury in different body region (head, chest, and abdomen) by seat belt status. As shown in tables 7A and 7B there is suggestive evidence to conclude that the use of seat belts would help decrease the AIS for chest injuries, but not necessarily the AIS for head injuries.

As shown in table 7C the severity of abdomen injury (AIS = 3+) is also higher if the seat belt was not used and also for the AIS = 2 the severity of abdomen injury is higher if the seat belt was used. Table 7D presents the maximum AIS for different body region (head, chest, neck, abdomen, spine, upper extremity, lower extremity and
burns) by seat belt use status. It shows that the severity of the injury is higher in cases not using seat belts for all AIS’s, except for AIS of 6, which might be attributed to other contributing factors such as the impact energy and crash scenario.

Table 7A: Seat belt usage and AIS – head injuries

<table>
<thead>
<tr>
<th>AIS Head</th>
<th>Seat belt Not used</th>
<th>Used</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>11</td>
<td>19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>40</strong></td>
<td><strong>30</strong></td>
<td><strong>70</strong></td>
</tr>
</tbody>
</table>

Table 7B: Seat belt usage and AIS – chest injuries

<table>
<thead>
<tr>
<th>AIS Chest</th>
<th>Seat belt Not used</th>
<th>Used</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35</strong></td>
<td><strong>19</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

Table 7C: Seat belt usage and AIS – abdomen injuries

<table>
<thead>
<tr>
<th>AIS Abdomen</th>
<th>Seat belt Not used</th>
<th>Used</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>13</strong></td>
<td><strong>10</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

Table 7D: Seat belt usage and maximum AIS

<table>
<thead>
<tr>
<th>Maximum AIS</th>
<th>Seat belt Not used</th>
<th>Used</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>14</td>
<td>32</td>
</tr>
<tr>
<td>4</td>
<td>16</td>
<td>3</td>
<td>19</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>61</strong></td>
<td><strong>46</strong></td>
<td><strong>107</strong></td>
</tr>
</tbody>
</table>

**Relationship between seat belt status by driver airbag condition**

The front airbag usually deploys for frontal impact, and normally does not protect the occupant during side, rear, or rollover accidents. Table 8A illustrates the driver’s seat belt status by driver’s airbag condition. It indicates that in 19 cases (29.7%, n=64) the driver did not use the seat belt but the steering wheel airbag deployed. This represents a life-threatening situation caused by the airbag impacting with excessive force on the driver/passenger not restrained by a seat belt.

Table 8A: Distribution of driver’s seat belt status and airbag deployment condition

<table>
<thead>
<tr>
<th>Driver airbag</th>
<th>Seat belt status Not used</th>
<th>Used</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployed</td>
<td>19 (59%)</td>
<td>13 (41%)</td>
<td>32 (100%)</td>
</tr>
<tr>
<td>Not activated/fitted</td>
<td>14 (44%)</td>
<td>18 (56%)</td>
<td>32 (100%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33 (52%)</strong></td>
<td><strong>31 (48%)</strong></td>
<td><strong>64 (100%)</strong></td>
</tr>
</tbody>
</table>

Table 8B presents the severity levels and seat belt status for the n=29 cases in which the airbag was deployed. It indicates 7 fatalities and 7 serious injuries for the cases that haven’t used the seat belt, even though the airbag was deployed. This indicates the high potential of serious injuries or fatalities in case of no seat belt use. This data
confirms that an airbag is a supplementary restraint system (SRS) which works most effectively if the seat belt is used.

### Table 8B: Severity levels and seat belt status with airbag deployed

<table>
<thead>
<tr>
<th>Severity</th>
<th>Seat belt</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
</tr>
<tr>
<td>Moderate</td>
<td>2 (33%)</td>
<td>4 (67%)</td>
</tr>
<tr>
<td>Serious</td>
<td>7 (54%)</td>
<td>6 (46%)</td>
</tr>
<tr>
<td>Fatal</td>
<td>7 (70%)</td>
<td>3 (30%)</td>
</tr>
<tr>
<td>Total</td>
<td>16 (55%)</td>
<td>13 (45%)</td>
</tr>
</tbody>
</table>

**Relationship between seat belt status by AIS for driver airbag condition**

Deployment of front airbags is not protective if the seat belt is not used. The minimum safe distance for a protective airbag deployment is around 25 cm. The space between the steering wheel and the driver seat is about 50 cm (without driver) and about 90 cm for the front passenger seat. If the driver is seated, the minimum safe space for airbag deployment might not be maintained, especially for overweight short drivers not wearing seat belt. Due to the crash impact in case the seat belt is not used, the driver moves fast towards the steering wheel, reducing the safe minimum space needed for a protective airbag deployment. This explains the observation of increased injury severity for cases not using a seat belt even when the airbag is deployed. Table 9 demonstrates the severity of injury for head and chest injuries by seat belt status for drivers if airbag was deployed. It shows that the injury severity for head and chest injuries is higher in cases where seat belt was not used.

### Table 9A: Seat belt status by AIS head and driver airbag deployed

<table>
<thead>
<tr>
<th>AIS Head</th>
<th>Seat belt</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
</tr>
<tr>
<td>1</td>
<td>1 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2 (67%)</td>
<td>1 (33%)</td>
</tr>
<tr>
<td>3</td>
<td>3 (75%)</td>
<td>1 (25%)</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>2 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>3 (50%)</td>
<td>3 (50%)</td>
</tr>
<tr>
<td>Total</td>
<td>11 (69%)</td>
<td>5 (31%)</td>
</tr>
</tbody>
</table>

### Table 9B: Seat belt status by AIS chest and driver airbag deployed

<table>
<thead>
<tr>
<th>AIS Chest</th>
<th>Seat belt</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not used</td>
<td>Used</td>
</tr>
<tr>
<td>1</td>
<td>2 (67%)</td>
<td>1 (33%)</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>4 (100%)</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>4 (67%)</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>5</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
</tr>
<tr>
<td>Total</td>
<td>11 (73%)</td>
<td>4 (27%)</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Road traffic is a complex system in which the various components interact with each other, comprising of three components – the human, the vehicle and the roadway environment. A road traffic crash is considered as a failure in the system. In this investigation road traffic crashes are analyzed to identify the contributing factors within the system components. The relative contribution of human, vehicle, and roadway environmental factors to the road traffic crashes have been analyzed in a number of studies using different methods. The in-depth crash investigation approach enables accurate assessment of crash contributing factors. This has been clearly illustrated by the preliminary analyses presented earlier. Although early to make general conclusions, the approach has been quite useful in identifying significant
proportions of the vehicle- (6.8%) and road/environment (19%) – related factors contributing to the crash injuries.

ACKNOWLEDGEMENT

This research is jointly funded by the Health Authority - Abu Dhabi and the RTTSRC-UAE University. The authors acknowledge the work and sincere efforts of the research project steering committee, SEHA and the involved hospitals for their support, and all the investigation team members and researchers.

REFERENCES


RTTSRC (2009). UAE Accident Rates, Causes and Interventions (National Transport Authority). study submitted to National Transport Authority, UAE


Contents session 10    Vehicle innovations and ITS applications

The Effectiveness of Antilock Brakes Systems on Motorcycles in Reducing Real Life Crashes and Injuries
Matteo Rizzi, Vectura Consulting, Sweden

Motorcyclist Spinal Injuries in Road Crashes: Literature Review
Zarir Hafiz Zulkipli, Malaysian Institute of Road Safety Research, Malaysia

Automated Truck Platoons on Motorways – A Contribution to the Safety on Roads
Eckart Hauck, RWTH Aachen University, ZLW/IMA, Germany

Mobile Traffic Safety Integration with off Board Navigation – (MOTION).
Evaluation of Acceptance and Traffic Safety with a Speed Alert Function
Magnus Hjälmdahl, VTI, Sweden

Atsushi Fukuda, Nihon University, Japan
The Effectiveness of Antilock Brake Systems on Motorcycles in Reducing Real-Life Crashes and Injuries

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3Swedish Road Administration, Monash University Accident Research Centre, Borlänge, Sweden

This study set out to evaluate the effectiveness of antilock brake system (ABS) technology on motorcycles in reducing real-life injury crashes and to mitigate injury severity. The study comprised an analysis of in-depth fatal crash data in Sweden during 2005–2008 to investigate the potential of ABS as well an estimate of the effectiveness of ABS in crash reduction in Sweden between 2003 and 2008 using induced exposure methods. Findings show that head-on collisions were the least ABS-affected crash types and collisions at intersections the most influenced. Induced exposure analysis showed that the overall effectiveness of ABS was 38 percent on all crashes with injuries and 48 percent on all severe and fatal crashes, with a minimum effectiveness of 11 and 17 percent, respectively. The study recommends the fitment of ABS on all new motorcycles as soon as possible and that customers only purchase motorcycles with ABS.

Keywords ABS brakes; Antilock brakes; Crash; Effectiveness; Injury; Motorcyclist

INTRODUCTION

Strandroth and Knudsen (2008) have shown that the risk of being killed on a motorcycle per passenger mile is approximately 20 times higher than for a passenger car occupant. The risk of being killed or severely injured in a crash has been the same since the 1980s for motorcycle riders, whereas according to Folksam (2009), the risk for passenger car occupants has systematically reduced by almost 75 percent. Figure 1 shows the number of persons killed or seriously injured (KSI) per 1000 casualty crashes.

During the last 10 years the number of motorcycles in Sweden has more than doubled, whereas the number of KSI has been relatively stable over this period. Consequently, this has lead to a reduction in the risk of KSI per 100,000 motorcycles as seen in Figure 2. Though this can be explained by a number of reasons, it is also conceivable that it may be due to an improvement in the likelihood of crashing a motorcycle over this time period.

The chain of events that eventually lead to a crash is described in Figure 3. With regards to passenger cars, systems have been developed to warn or support drivers (i.e., intelligent speed assistance), to intervene in driving (i.e., lane departure warning), or to immediately correct poor driving maneuvers (i.e., electronic stability control, ESC). The challenge is yet to find, evaluate, and introduce corresponding safety equipment for motorcycles. One technology, antilock brake systems (ABS), has been introduced on a range of motorcycles since the late 1980s and could be considered similar to ESC on passenger cars, because they both act by immediate correction when a critical situation is detected. However, such a comparison may be limited because ABS relates to stability while braking only.

An analysis of in-depth studies by Sporner and Kramlich (2003) has shown that the majority of motorcycle crashes with other motor vehicles involve braking and that injury severity increases when motorcycle riders fall prior to collision. ABS on motorcycles uses electronic controls to maintain wheel rotation under hard braking. In a situation that would normally lock the wheel, ABS increases the motorcycle’s stability, preventing it from falling to the ground, as pointed out by Teoh (2008). The system also provides the motorcyclist with the necessary confidence to apply the brakes up to the limit of the friction available (Elliott et al. 2003), therefore possibly increasing deceleration as shown by Vavryn and Winkelbauer (2004). This is especially the case when ABS is combined with combined brake systems (CBS), which makes it easier for the rider to distribute the brake force between the back and front wheel more optimally (Green 2006).

In passenger cars, Evans (1998) has shown that ABS has had only a minor effect in reducing the number of crashes, whereas according to Lie et al. (2005), ESC has decreased crash
involvement and injury severity markedly. The effect of ABS on motorcycles might be expected to be greater than for passenger cars because of possible instability problems from locked wheels. Teoh (2008) compared fatal crash involvements by total registered vehicle years for ABS and non-ABS motorcycles and showed that motorcycles equipped with ABS had a 38 percent lower crash involvement rate, although these results were not statistically significant.

Though ABS was first introduced on the market 20 years ago, currently only a minority of new motorcycles in Sweden sold by major manufacturers in the region are equipped with ABS as standard. On other models, ABS is offered as optional equipment. Only one manufacturer has equipped almost the entire range of motorcycle models with ABS since the late 1990s.

STUDY OBJECTIVES

The main objectives of this study were to:

1. investigate the potential of ABS to reduce fatal motorcycle crashes in Sweden;
2. find out which crash types are most influenced by ABS;
3. estimate the effectiveness of ABS on motorcycles in reducing crashes with injuries in Sweden; and
4. examine whether ABS on motorcycles affects injury severity in crashes.

METHOD

This project was divided into two parts. Study 1 used in-depth studies of fatal crashes in order to investigate the potential of ABS to reduce crashes and injuries and to find out in which type of crashes ABS would be of relevance. Such findings were then used in Study 2 to estimate the effectiveness of ABS in crash reduction using an induced exposure approach. A comparison of injury severity in crashes with, and without, ABS was also undertaken.

Study 1

Sferco et al. (2001) used a decision-tree approach to judge the potential of ESC to reduce real-life crashes. A similar approach...
was adopted here using a scale from 1 to 5 to rank the likely influence of ABS on fatal crashes and to determine which types of events are most influenced by ABS (see Figure 4). The decision-tree scale was defined as follows:

1. ABS would definitely not have influenced the crash
2. ABS would perhaps have influenced the crash
3. ABS would probably have influenced the crash
4. ABS would definitely have influenced the crash
5. ABS could definitely have avoided the crash

The sequence of events was analyzed for each crash using information from in-depth investigations of fatal crashes stored in a database at the Swedish Road Administration (SRA). A fatal accident involving an ABS-equipped motorcycle would automatically get a score of 1. Though braking before the crash, as well as a fall prior to collision, are normally simple to detect, it was more complex to determine whether braking was a crucial event or not. Information in the database such as driving speed, assumed reaction time, actual braking distance (i.e., from skid marks), road condition, and so on were taken into account in making these judgments. The methodology of the in-depth analysis was developed by the analysis team, which also analyzed together a number of typical crash types in order to reach consensus in the judgment with the scale. After this initial step, the remaining crashes were analyzed by a single road safety analyst. However, the analysis team was consulted to get objective results. By examining the distribution of scores 1–5 for different crash types, it was then possible to determine under which circumstances ABS would have (or not have) affected the outcome of the crash. The least ABS-affected crash type was thus considered to be nonsensitive to ABS in the follow-up analysis in Study 2.

**Study 2**

An analysis using induced exposure can be used when true exposure is not available, as shown by Evans (1998) and Lie et al. (2005). Using this approach, it is assumed that the ratio between the number of crashes in sensitive and nonsensitive situations to ABS should not differ between two groups of vehicles with the same risk of crash involvement. If the ratio is different for two groups, where the only noteworthy difference is ABS, it is assumed that the difference is due to ABS. The effect of ABS is considered to be zero if $R$ in Eq. (1) is equal to 1.

$$R = \frac{A_{\text{ABS}}}{N_{\text{ABS}}} \div \frac{A_{\text{non-ABS}}}{N_{\text{non-ABS}}}$$

where $A_{\text{ABS}}$ = number of crashes sensitive to ABS, involving motorcycles with ABS; $A_{\text{non-ABS}}$ = number of crashes sensitive to ABS, involving motorcycles without ABS; $N_{\text{ABS}}$ = number of crashes nonsensitive to ABS, involving motorcycles with ABS; and $N_{\text{non-ABS}}$ = number of crashes nonsensitive to ABS, involving motorcycles without ABS.

Thus, the effectiveness in crash reduction can be expressed as:

$$E = 100 \times (1 - R)\%$$

The standard deviation of the effectiveness was calculated on the basis of a simplified odds ratio variance, according to Eq. (3). This method gives symmetric confidence limits but the effectiveness is not overestimated.

$$Sd = R \times \sqrt{\frac{1}{n_i}}$$

where $n$ is the number of crashes of each type. The 95 percent confidence limits are given in Eq. (4).

$$\Delta E = 100 \times R \times Sd \times 1.96$$

Motorcycles are generally divided into a number of different types or categories, such as standard (also known as naked), off-road, touring, sport touring, sport, on/off (also known as dual-sport), and cruiser. Crash data involving motorcycles with ABS were only available for the categories touring, sport touring, on/off, and standard in this analysis. This is because there are very few ABS-equipped models among sport and cruiser models, which were only introduced in Sweden from 2008 and 2009 and are not represented in Swedish crash records yet.

Because the number of crashes involving the same models, with and without ABS, was too small to compare directly, case and control motorcycles were divided according to the category criteria. Motorcycles within each category were expected to have approximately the same characteristics regarding performance, seating position, brake and frame construction, et cetera, and were therefore estimated to have comparable crash rates. Checks were also carried out to ensure that both ABS and non-ABS groups were representative of the population at large.

Some motorcycles have ABS as standard equipment, whereas others have it as an option. In such cases, a number of manufacturers were contacted in order to retrieve information about ABS through the chassis number of those motorcycles. During this process, the crash data were handled according to confidentiality restrictions.

Finally, an attempt was made to investigate whether crashing with an ABS-equipped motorcycle might influence injury severity, compared to a non-ABS-equipped motorcycle. Personal injuries in ABS and non-ABS groups were compared using ISS (Injury Severity Score), AIS (Abbreviated Injury Scale), and MAIS (Maximum Abbreviated Injury Scale). Crash type distributions were also taken into account to determine whether any difference might relate to ABS or to other confounders.

**MATERIAL**

**Study 1**

The Swedish Road Administration has been carrying out in-depth studies for each fatal road crash since 1997. The vehicles involved and the crash site are inspected by crash investigators...
at SRA and more information is provided by the police, rescue services, and forensic medicine.

This study was based on 164 in-depth fatal motorcycle crashes in Sweden between 2005 and 2008. Crashes with any category of motorcycles with engine displacement over 125cc were included in the analysis.

Study 2
Data for Study 2 were taken from STRADA (Swedish Traffic Accident Data Acquisition) and include police-reported crashes with at least one injured person. Motorcycle crashes between 2003 and 2008 were analyzed where the case group contained motorcycles manufactured from 1997 to 2008, with a nominal engine power of at least 25 kW. As mentioned earlier, all case and control motorcycles belonged to categories including touring, sport touring, on/off, and standard and were manufactured during the same time period and with an engine developing at least 25 kW (see Table I).

Police-reported crash data are generally known to suffer from a number of data quality problems. Because it was assumed that this limitation would equally affect both categories, it was not expected to affect this analysis.

Hospital-reported data were also used to compare injuries in crashes involving motorcycles with and without ABS. Again, crash data from 2003 to 2008 were acquired through STRADA. Because hospital-reported crash data do not include any technical specifications about vehicles, case and control groups could only be compared by matching police-reported crashes with hospital-reported ones. In total, 72 cases and 354 control motorcycles were identified from this process.

RESULTS
Study 1
Analysis of 164 in-depth studies of fatal motorcycle crashes showed that 14 percent of crashes could have been avoided with ABS and further 16 percent would have definitely been influenced by ABS. It was unclear to what degree ABS could have influenced the outcome of 22 percent of the crashes. These results are illustrated in Figure 5. In 66 percent of the cases, the motorcycle rider did brake before the crash. In a further 18 percent of crashes, the rider fell prior to the collision. When motorcycle–motor vehicle collisions were analyzed separately, braking before crash was found in 75 percent of cases, and falls prior to collision occurred in 27 percent of cases. Crash type was then taken into account to determine in which circumstances ABS would have affected the outcome of a crash. Results are shown in Table II. These results show that 31 percent of crashes at intersections could have been avoided entirely with ABS, and in another 21 percent of the cases, ABS would have been expected to have definitely influenced the outcome. Alternatively, ABS was considered not to have had any significant influence on the outcome in 57 percent of head-on collisions and 51 percent of single-vehicle crashes. In only 14 percent of the head-on collisions analyzed could ABS have probably influenced the outcome. Instead, the outcome of 31 percent of single-vehicle crashes was judged to have been influenced to some degree.

Study 2
Based on the results of Study 1, head-on collisions were the least ABS-affected crash type among the analyzed fatal crashes. The effectiveness of ABS was therefore estimated by considering head-on collisions as nonsensitive events (crash types) in the Study 2 analysis. Comparisons were carried out to ensure that case and control groups had similar distributions of crash types among the motorcycle population involved in road crashes in

Table I Number of motorcycles used for the calculations per category (see appendix for motorcycle models in each category)

<table>
<thead>
<tr>
<th>Motorcycles category</th>
<th>Number of case motorcycles</th>
<th>Number of control motorcycles</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touring</td>
<td>61 (33%)</td>
<td>104 (11%)</td>
<td>165</td>
</tr>
<tr>
<td>Sport touring</td>
<td>45 (24%)</td>
<td>145 (15%)</td>
<td>190</td>
</tr>
<tr>
<td>On/off</td>
<td>52 (28%)</td>
<td>250 (25%)</td>
<td>302</td>
</tr>
<tr>
<td>Standard</td>
<td>29 (16%)</td>
<td>486 (49%)</td>
<td>515</td>
</tr>
<tr>
<td>Sum</td>
<td>187 (100%)</td>
<td>985 (100%)</td>
<td>1172</td>
</tr>
</tbody>
</table>

Figure 5 The potential of ABS on fatal motorcycle crashes in Sweden between 2005 and 2008.

Figure 6 Sensitive (all crashes excl. head-on collisions) to nonsensitive (head-on collisions) ratios in the control group, per driver age.
Sweden. This ensured that the ABS and non-ABS groups were representative samples of the motorcycle population and the effectiveness of ABS would not be compromised. Calculations showed similar distributions (if not identical) for almost all crash types. With regard to non-ABS-sensitive crashes in particular, the sharing of head-on collisions in the case group (13%) was slightly greater than in control group (8%). According to official crash records, head-on collisions amounted for 7 percent of all crashes with injuries between 2003 and 2008, which means that both case and control groups have greater distributions of non-ABS-sensitive crashes. This suggested that the effectiveness would not be overstated.

Further calculations were made within the control group to verify that the only noticeable difference was ABS. This was done by analyzing the variation of the ratio, $\frac{N_{\text{abs}}}{N_{\text{non-abs}}}$ (see Eq. (1)), depending on a number of factors such as speed limit, road condition, driver age and gender, vehicle age, weight-to-power ratio, and motorcycle category. No substantial variations from the overall results were found except for riders aged 20 to 24 years and for older drivers, which showed a greater sensitive-to-nonsensitive ratio (see Figure 6). Logically, this difference could harm the analysis as riders between 20 and 24 were involved in more ABS-sensitive crashes than the rest of the control group. However, as they amount for only 12 percent of the population within the control group, it was calculated that this variation was only likely to have a minor affect on the results.

The findings of the analysis with induced exposure are shown in Table III. All results are statistically significant. The reduction in crash involvement for ABS was estimated to be 41 percent for all crashes relative to head-on collisions and 43 percent for crashes at intersections. The lower 95 percent confidence limit is quite similar for both these comparisons. The effectiveness of ABS on severe and fatal crashes compared with head-on collisions was 38 percent for all casualty crashes and 48 percent for all severe and fatal crashes. The lower confidence limit was 11 percent for all casualty crashes and 17 percent for severe and fatal injuries, and the upper limits were 65 percent and 79 percent, respectively.

Table V shows the injury severity outcome in all casualty crashes involving ABS- and non-ABS-equipped motorcycles. Comparisons were made in order to comprehend whether any possible difference could have been related to ABS. Again, the sharing of head-on collisions in the case group was greater than in the control group (9 and 5%, respectively). As seen in Table V, crashes involving ABS motorcycles generally resulted in fewer severe injuries. Though the distribution of most severe injury (MAIS 3+) does not differ substantially, the injury severity score is about 100 percent greater for controls than cases for the more severe injuries (ISS 16 or greater) and 130 percent greater for AIS 3+ injuries.

**DISCUSSION**

Two different analyses were presented in this article and these will be discussed separately. However, it should be noted that though the scale of potential (Sferco et al. 2001) and induced exposure (Evans 1998; Lie et al. 2005) has been used before to estimate the benefits of other safety systems, this was the first attempt to combine both methods. Caution should be taken in drawing general conclusions from these findings due to the limited number of crashes. Because Study 2 is based on the results of Study 1, it should also be noted that the result from the analysis of the in-depth studies can directly affect the analysis with induced exposure. It is therefore important that further

<table>
<thead>
<tr>
<th>Table II</th>
<th>The potential of ABS on fatal motorcycle crashes in Sweden between 2005 and 2008, per crash type</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABS scale</td>
<td>Head on</td>
</tr>
<tr>
<td>n = 28</td>
<td>n = 65</td>
</tr>
<tr>
<td>1 ABS would have definitely not influenced the crash</td>
<td>57%</td>
</tr>
<tr>
<td>2 ABS would have perhaps influenced the crash</td>
<td>29%</td>
</tr>
<tr>
<td>3 ABS would have probably influenced the crash</td>
<td>14%</td>
</tr>
<tr>
<td>4 ABS would have definitely influenced the crash</td>
<td>0%</td>
</tr>
<tr>
<td>5 ABS could have definitely avoided the crash</td>
<td>0%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table III</th>
<th>The effectiveness of ABS in crashes mitigating injury (with 95% confidence limits) relative to head-on collisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All crashes with injury excl. head-on collisions</td>
<td>41% +/- 29%</td>
</tr>
<tr>
<td>Crashes in intersections</td>
<td>43% +/- 32%</td>
</tr>
<tr>
<td>All severe and fatal crashes excl. head-on collisions</td>
<td>54% +/- 35%</td>
</tr>
<tr>
<td>Severe and fatal crashes in intersections</td>
<td>71% +/- 29%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table IV</th>
<th>The overall effectiveness of ABS on all casualty crashes as well as severe and fatal crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All casualty crashes</td>
<td>38% +/- 27%</td>
</tr>
<tr>
<td>All severe and fatal crashes</td>
<td>48% +/- 31%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table V</th>
<th>Injury severity in crashes involving motorcycles with and without ABS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury</td>
<td>Case motorcycles n = 72</td>
</tr>
<tr>
<td>AIS 3+</td>
<td>8.7%</td>
</tr>
<tr>
<td>MAIS 3+</td>
<td>5.6%</td>
</tr>
<tr>
<td>ISS 9-15</td>
<td>11.1%</td>
</tr>
<tr>
<td>ISS 16-75</td>
<td>5.6%</td>
</tr>
</tbody>
</table>
studies using even greater numbers of in-depth cases are carried out in the future when more motorcycles with ABS will be represented in fatal crash records. Though the figures seem very promising, more research is needed.

**Study 1 Findings**

From the analysis of the SRA in-depth fatal crash data, it was found that head-on collisions were the only crash type for which ABS seemed to be ineffective. For the others, analysis revealed likely effectiveness figures from 17 to 21 percent for definite influence by ABS and possible crash avoidance for ABS in 31 percent of intersection, 20 percent of rear-end, and 5 percent of single-vehicle collisions.

The analysis with the in-depth crash data showed that in 75 percent of the motorcycle–other motor vehicle collisions, the motorcycle rider did apply the brakes before the crash, suggesting that braking is relevant and important in motorcycle crashes. Furthermore, in 27 percent of crashes the rider fell prior to the collision, which highlights the instability problem. These figures are somewhat greater, but still in the same magnitude, as other values shown by Sporn and Kramlich (2003), where 65 percent of collisions between motorcycles and other motor vehicles involved braking and around 12 percent for a fall before the collision.

It was found by analyzing the in-depth studies that head-on collisions were the least ABS-affected crash type and therefore assumed to be nonsensitive to ABS. Such results are reasonable. Motorcycle riders are rather unprotected compared to passenger car occupants. It is logical that braking prior to head-on collisions may not be the most efficient crash avoidance maneuver to perform. Though it might be expected that ABS would generally improve stability during braking and perhaps provide those split seconds needed to avoid the collision, it did not seem to show such potential in these head-on collisions.

It should also be noted that the scale of potential was not a subjective judgment but related to a number of objective facts such as brake marks, road condition, driving speed, et cetera.

**Study 2 Findings**

The results using the STRADA 2003–2008 data showed impressive reductions in crash involvement for ABS technology on motorcycles. The overall effectiveness for ABS including head-on collisions was 38 percent for all casualty crashes and 48 percent for all severe and fatal crash outcomes. The reductions in crash involvement were even more impressive using head-on crashes as a control, estimated to be 41 percent for all other crashes, and up to 43 percent for crashes at intersections alone. The effectiveness on severe and fatal crashes at intersections was even higher at 71 percent.

A critical assumption for Study 2 was that different motorcycle models and riders within the same category were assumed to have similar crash risks. Though the concept of crashworthiness does not apply to motorcycles, Ulleberg (2003) has pointed out that no evidence of relation between crash risk and engine size or power has been found.

The induced exposure method employed here was based on the category criteria due to the lack of sufficient crash data and should be therefore regarded as only a first step using this new approach. Even though it may be reasonable to compare similar motorcycle models with similar properties, it is still important to ensure that the only relevant difference is ABS and not other confounding factors. Of some comfort, an analysis conducted to verify this showed no considerable variation between case and control riders except for rider age, as mentioned before.

Compared to other studies that have evaluated ABS on motorcycles and that are based on true exposure like vehicle mileage, number of vehicles in traffic (Teoh 2008), or insurance data (Moore and Yan 2009), induced exposure is more robust. When using true exposure, many confounders can affect the results. The only critical issue with induced exposure is to make sure that there is no decisive anomaly between the case and control cases. The only major deviation found in this study concerned riders of ages between 20 and 24, who had a higher proportion of non-ABS-sensitive crashes, although it was argued that because they only represent 12 percent of the control group, this factor would have only had a minor influence, if any, on the results.

Though these results seem extraordinary, they are in line with other recent reports regarding ABS on motorcycles, albeit of greater magnitude. Sporn and Kramlich (2003) estimated that introducing ABS on all motorcycles would reduce crashes by around 10 percent, thus with a “theoretical presupposition for positive influence by ABS in more than 50 percent of all crashes.” Moore and Yan (2009) showed a 19 percent reduction in frequency of insurance claims with ABS-equipped motorcycles. Furthermore, Teoh (2008) has found that ABS can reduce fatal motorcycle crashes per 10,000 registered vehicles by 38 percent. Sporn and Kramlich (2003) have also reported a reduction of MAIS 4+ injuries if the motorcycle rider is sitting on an upright position when a crash occurs. Explanations for the effects on both crash reduction and injury severity can speculatively be related to the dual function of ABS. Vavra and Winkelbauer (2004) have shown that ABS not only increases the achievable deceleration but also improves stability in an emerging situation. Both functions may reduce injury severity because improved stability during braking would reduce the risk of fall prior to collision and increased deceleration would reduce collision speed. However, stability improvements might be the biggest advantage of ABS. The possibility of full braking and changing trajectory at the same time in a critical situation could allow riders to totally avoid the crash. At the moment, though, very little is known regarding the possible dual effect of ABS on motorcycles.

Though Evans (1998) has shown the disappointing results of ABS for passenger cars, Lie et al. (2005) have proven that ESC has such a dual effect. Based on the results of this study, it could be appropriate to compare the importance of ESC for passenger cars with ABS for motorcycles, because they both act on vehicle stability when a critical situation emerges (see Figure 3) and provide more favorable conditions during the crash. Clearly, such a comparison may be difficult.
to demonstrate because ABS relates to stability while braking only. The possible effect of ABS in reducing falls prior to collision, however, can be of relevance to the implementation of other crash protection systems on motorcycles. Though the introduction of airbags on the market is still very limited, a possible interaction between ABS and airbags seems promising and needs to be further investigated. Unfortunately, the limited number of models with airbags and ABS makes such task impossible at the moment. Furthermore, the increased deceleration and possible decreased impact speed with ABS can favor the effectiveness of other crash protection systems, such as helmets, protective clothing, and motorcycle-friendly barriers.

It is possible that riders on ABS-equipped motorcycles in Sweden may adopt more risky behaviors by driving faster or braking later if they believe that ABS could help them manage dangerous braking situations. It is believed that this may motivate the rider to compensate for the safety system advantages and push the safety level back to the same as before the safety system was introduced. In any case, in this study, it would have led to underestimating the effectiveness and the results would be conservative. As when all new safety systems are introduced, risk compensation is possible, and this effect cannot be ignored. Such behavior has been suspected by Evans (1998) on passenger cars with ABS. Evaluation of safety systems that seek to prevent injuries should always be conducted as soon as possible after their implementation. This is a key factor in understanding the advantages and disadvantages and also to be able to push for a broader and more rapid penetration of promising safety systems. However, it is important to stress that the results were based on crashes in Sweden only, which is a rather small country with limited numbers of crashes. Therefore, the possibility to draw general robust conclusions from these results also is quite limited. That shows the need of these studies being more broad and multinational, possibly by joining many countries as proposed by Lie et al. (2005).

With respect to ABS on motorcycles, this would allow analysis on a broader set of crash data involving other types of motorcycles (i.e., scooters) and different motorcycling cultures. Weather conditions in Sweden are different from other countries, which makes motorcycling somewhat of a seasonal activity. This is apparent in crash statistics too, because the majority of motorcycle crashes occur under favorable weather conditions. Besides, motorcycles involved in crashes in Sweden are mainly heavier vehicles, ridden outside urban areas during free time. This is not the case in other parts of the world. The European Transport Safety Council (ETSC, 2008) indicates that in southern Europe, for instance, more fatal crashes are reported inside urban areas than outside. It would be of major interest to investigate the effectiveness of ABS in other countries where lighter motorcycles are widely used too, possibly throughout the year, with various road conditions and in different traffic environments. Such investigations could then validate the results of this study as well as others. In the meanwhile, there is reason to believe that ABS provides much needed help in managing critical situations, thus avoiding crashes and saving lives. The motorcyc-

ple industry should therefore be encouraged to implement ABS on all categories of motorcycles, and customers should purchase ABS-equipped models.

**CONCLUSIONS**

There were a number of important major findings from this research:

- The potential of ABS in reducing fatal motorcycle crashes in Sweden is approximately 30 percent.
- The overall effectiveness of ABS in Sweden was 38 percent on all crashes with personal injuries and 48 percent on severe and fatal crashes. The minimum effectiveness ranged from 11 to 17 percent, respectively. The effectiveness on severe and fatal crashes in intersections was estimated to be at least 42 percent.
- Injury severity in crashes with ABS-equipped motorcycles is markedly lower than in similar ones with non-ABS-equipped motorcycles.
- Head-on motorcycle collisions are not, or only slightly, affected by ABS.

**RECOMMENDATIONS**

- Manufacturers should work toward introducing ABS equipment on new motorcycles in each category in Sweden.
- Customers should be encouraged to only purchase motorcycles fitted with ABS technology.
- Further studies on a larger scale should be made in order to validate the results of this study and to investigate possible risk compensation behaviors.

**ACKNOWLEDGEMENTS**

This study has been financed by the Skyltfonden project at SRA. Many thanks to Brian Fildes at MUARC for reviewing and improving the manuscript. Many thanks also to Anita Ramstedt, Mats Artebranth, Jörgen Persson, and Ylva Berg at SRA; Jenny Eriksson at Vectura Consulting AB; Kristina Mattsson at Swedish Transport Agency; and the Swedish branches of BMW, Honda, Suzuki, Kawasaki, and Yamaha for valuable support in providing data on ABS equipment.

**REFERENCES**


APPENDIX

The tables below show the motorcycle models included in the induced exposure analysis.

<table>
<thead>
<tr>
<th>Case motorcycles n = 29</th>
<th>Control motorcycles n = 486</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Category</strong></td>
<td></td>
</tr>
<tr>
<td>BMW R 1100 R</td>
<td>BMW R 850 R</td>
</tr>
<tr>
<td>BMW R 1150 R</td>
<td>BUELL M2 CYCLONE</td>
</tr>
<tr>
<td>BMW R 850 R</td>
<td>BUELL S1 LIGHTNING</td>
</tr>
<tr>
<td>HONDA CB 1300 SA</td>
<td>BUELL X1 MILLENIUM</td>
</tr>
<tr>
<td>HONDA CB 600 FA</td>
<td>BUELL XB12 X</td>
</tr>
<tr>
<td>HONDA CBF 1000 A</td>
<td>BUELL XB9 S</td>
</tr>
<tr>
<td>HONDA CBF 600 SA</td>
<td>CAGIVA V-RAPTOR</td>
</tr>
<tr>
<td>KAWASAKI ER-6 N ABS</td>
<td>DUCATI GT1000</td>
</tr>
<tr>
<td>KAWASAKI Z 750 ABS</td>
<td>DUCATI MONSTER</td>
</tr>
<tr>
<td>SUZUKI GSF 1200 SA</td>
<td>DUCATI MONSTER 1000 S</td>
</tr>
<tr>
<td>YAMAHA FZ6 N ABS</td>
<td>DUCATI MONSTER 600-620</td>
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<tr>
<td>YAMAHA FZ6 S ABS</td>
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MOTORCYCLIST SPINAL INJURIES IN ROAD CRASHES:
LITERATURE REVIEW

Zarir H.Z, Abdul Rahmat A.M, Noor F.P, Wong S.V.
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ABSTRACT

Study Design: This study is essentially an extensive review of literature of spinal injuries sustained by motorcyclists. Objectives: The objectives of the review are to (i) determine the prevalence of spinal injuries in motorcycle crashes; (ii) to show the significance consequences of spinal injuries and its related social burden; (iii) to identify spinal injury pattern and mechanism; (iv) to highlight the current gap on the impact biomechanics specifically for motorcyclist spinal injuries. Background Data: Spinal injury studies on motorcyclists involved in road crashes. Method: All literature on road crashes was reviewed to identify publications pertaining to road crash research on spinal injuries. Findings: Based on the literature review, it is found that motorcyclists indeed sustain spinal injuries which frequently have devastating effects on the motorcyclists especially those involving spinal cord injuries. Most authors have reported a low incident rate for spinal injuries, with significant cases of missed injuries and also under-reporting of spinal injuries. Based on population based study, the closest percentage of spine injury prevalence is 7%. Spinal injuries should be accorded a high priority because of its enormous social burden and cost. The most critical part of the spine is the cervical as the review indicates a high mortality rate among motorcyclists who suffer cervical injuries. The thoracic spinal area is also another critically important area because injuries to the thoracic spine often cause neurological impairment and also occur at a similarly high rate. To date there has been very little study done on impact biomechanics related to motorcycle crash. Most important advance in biomechanics response has been broadly explored for passenger car leaving a gap to the development of similar model specifically for motorcycle. Conclusions: Research on spinal injury due to motorcycle road crashes should be expanded to include experimental and validation tests in order to provide important information on crash and injury mechanism to improve vehicle design that may help reduce injuries, specifically spinal injuries.
1 INTRODUCTION
Spinal injury is one of the most devastating injuries to be sustained during a motor vehicle crash. Although, spinal injuries sustained during motorcycle crashes are reported to be low, the social burden of spinal injury is immense. It is reported that spinal injuries incur societal costs of up to 5 to 10 billion Euros and are on the increase in Europe (Morris et al. 1996). This is due to the potential for long term impairment, inherent in spinal injuries. Motorcyclist is a high risk group and generally susceptible to high velocity injury and multiple traumas. Patient with multiple trauma present a major diagnostic problem as some spine injuries are not readily apparent during initial examination. In addition, in fatal case, spine injuries especially cervical spine might be underreported because it is are not routinely examined by forensic especially when the obvious reason of death is more pronounced such as head injury (Pang et al., 1999).

Moreover, information on spine injury mechanism in motorcycle road crash is quite limited. Much effort is concentrated on car passenger road crash. For instance the Neck Injury Criteria (NIC) during rear-end collision had served as validation tool to understand whiplash injury (Bostrom et al., 1996). Thus far, there were no spine injury criteria or model specifically designed to investigate spine injury due to motorcycle crash. Hence, this review examines the prevalence, pattern, mechanism of spinal injuries among motorcyclist in road crashes. It also highlights the current gap on the impact biomechanics that is far less develop for motorcycle compare to passenger car.

2 METHODS
The main literature search was conducted using Science Direct, PubMed and Medline. Other additional references from local journal such as Malaysian Medical Journal also were gathered. Areas of interest are literatures on injury pattern in motorcycle collision, prevalence of spinal injury, spinal injury mechanism, biomechanics of spine, fracture of cervical, thoracic and lumbar, cost of spinal injury, injury criteria and tolerance of spinal injury and lastly any related work on of spinal biomechanics. Keyword used for the literature search is motorcycle, spine, spine injury, spine biomechanics, cervical, thoracic and lumbar fracture, injury tolerance and criteria of spine, cost of spinal injury and spine modeling. In all, 551 papers from 1975 to 2009 were gathered and reviewed by the authors and 42 papers were selected for final paper.

3 PREVALENCE OF SPINE INJURIES
The estimation of population at risk in the context of road safety is theoretically best described using passenger per kilometer travel (PKT) or vehicle kilometer travel as a denominator to truly represent the population at risk. However, to the best of authors’ knowledge, there was no work on the risk of motorcycle to sustain spinal injury based on PKT or VKT were conducted before. The next alternatives are perhaps population based study and hospital based study. Through this literature review the authors identify 3 population based study and 6 hospital based study on motorcycle collision. Table 1 show that spinal injury prevalence varies between 1 to 10 % of the total sample from different types of studies. This wide range of studies outcome does not give any good conclusion on accuracy of spine injury prevalence. However the author argues that to draw a conclusion based on single trauma center would not reflect the true extent of the
problem thus population based study would be better alternative. For this particular literature review the percentage of spinal injury is approximately 7% with the worst acceptable result of 1 to 3%.

Table 1: Percentage of Spine Injuries from Different Literatures

<table>
<thead>
<tr>
<th>Author</th>
<th>Study Year</th>
<th>Region/Country</th>
<th>Type of Study</th>
<th>Data Sources</th>
<th>Total Sample</th>
<th>Spinal Incidence</th>
<th>Percentage of Spinal Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drysdale et al.</td>
<td>1975</td>
<td>Sacramento County</td>
<td>Population-based/Retrospective study/All injuries</td>
<td>Medical admission records, Police reports, Death Certificates</td>
<td>1273 patients</td>
<td>19 patients</td>
<td>1.49%</td>
</tr>
<tr>
<td>Deaner et al.</td>
<td>1971-1973</td>
<td>Naval Regional</td>
<td>Hospital-based/Retrospective study/All injuries</td>
<td>Medical admission records</td>
<td>324 persons/240 fractures</td>
<td>16 fractures</td>
<td>6.60%</td>
</tr>
<tr>
<td>Mary Braddock et al.</td>
<td>1985-1987</td>
<td>Connecticut US</td>
<td>Population-based/Retrospective Study/All injuries</td>
<td>Medical admission records for hospital discharge and acute care hospital, Police reports</td>
<td>9250 total injuries</td>
<td>647 vertebra and spinal</td>
<td>7%</td>
</tr>
<tr>
<td>Begg et al.</td>
<td>1988</td>
<td>New Zealand</td>
<td>Hospital-based/Retrospective study/All injuries</td>
<td>National Mortality File for all public hospitals</td>
<td>2623 case</td>
<td>Not mention the number only percentage of total case of Spinal and Trunk</td>
<td>9%</td>
</tr>
<tr>
<td>Sinha et al.</td>
<td>1989-1990</td>
<td>Mersey Region and North Wales UK</td>
<td>Hospital-based/Retrospective study/Severe injuries</td>
<td>16 district general and teaching hospitals in Merseyside, North Wales and the Isle of Man</td>
<td>1088 severe cases</td>
<td>4/30 for fatal and 15/175 from total injuries</td>
<td>13% (F) and 23% (N)</td>
</tr>
<tr>
<td>Jess Krauss et al.</td>
<td>1991-1992</td>
<td>California US</td>
<td>Population-based/Retrospective study/All injuries</td>
<td>11 California counties, hospital records/Police records</td>
<td>548 fatal and 4214 non fatal</td>
<td>17 for fatal and 155 for non fatal</td>
<td>3.1% (F) and 3.7% (N)</td>
</tr>
<tr>
<td>Ankarath et al.</td>
<td>1993-1999</td>
<td>Yorkshire Region</td>
<td>Hospital-based/Retrospective study/All injuries</td>
<td>Trauma unit in Yorkshire</td>
<td>1239 patients</td>
<td>129 patients</td>
<td>10.40%</td>
</tr>
<tr>
<td>Lin et al.</td>
<td>1994-1996</td>
<td>Taipei</td>
<td>Junior college students</td>
<td>8 junior colleges in Taipei (urban) and two colleges in Hualien (rural)</td>
<td>1284 students</td>
<td>11 students</td>
<td>0.60%</td>
</tr>
<tr>
<td>Zargar et al.</td>
<td>1999-2000</td>
<td>Iran</td>
<td>Hospital-based/Retrospective study/All injuries</td>
<td>6 hospitals in Tehran</td>
<td>1332 patients</td>
<td>16 patients</td>
<td>1.20%</td>
</tr>
<tr>
<td>Pang et al.</td>
<td>1998</td>
<td>Klang Valley Malaysia</td>
<td>Hospital-based/Prospective study/All injuries</td>
<td>3 hospitals in Kuala Lumpur</td>
<td>412 cases</td>
<td>7 patients</td>
<td>1.69%</td>
</tr>
</tbody>
</table>

*specific spine segment unknown

3 SPINAL INJURY OUTCOMES

The number of people affected by spinal cord or spinal injury is increasing nationally, following similar trend of rapid development and increasing number of building constructions sites, and motor vehicles. Spinal injury due to motor vehicle accidents accounted for highest percentage followed by fall from height (Roohi et al. 2006, Leonard et al. 2009). Spinal injury may often lead to disability or even sometimes death.
3.1 Mortality and disability
Normally, cervical spinal injury associated with ISS score of 75 is commonly a cause of mortality (Ankarath et al. 2002). In Thailand motorcycle accidents were cause to 80% of the brachial traumatic plexus injuries (Songcharoen, 1995). Also, Kasanthikul et al. (2002) demonstrated that more than half of motorcyclist died due to the injury at the upper cervical spine. The National SCI Statistical Centre, University of Alabama (2008) reports that life expectancy for persons with spinal injury who survived at least 24 hours post-injury is as shown in Table 2.

Table 2: Life expectancy for patients with spinal injury (National SCI Statistical Centre, University of Alabama, 2008).

<table>
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<tr>
<th>Age at Injury</th>
<th>Normal</th>
<th>Paraplegia (Partial)</th>
<th>Quadriplegia (Total)</th>
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<td>20 years</td>
<td>56.0</td>
<td>32.7</td>
<td>30.5</td>
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<td>40 years</td>
<td>37.2</td>
<td>17.4</td>
<td>15.7</td>
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<tr>
<td>60 years</td>
<td>20.4</td>
<td>6.1</td>
<td>4.8</td>
</tr>
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</table>

Although neurologic injuries are low in spinal fractures the consequence often resulted in permanent disability especially those suffered from complete neurologic injury. Thoracic spine region recorded the highest occurrence of the neurologic injury in motorcyclist spinal injuries (Robertson et al., 2002; Kupferschmid et al. 1989; Daffner et al. 1987; Quinlan et al. 2005). The worst outcome from complete neurologic injury would be quadriplegia and paraplegia. Quadriplegia caused a person to lose the sense of feeling and is not able to move both upper and lower limbs and this is caused by injury to the cervical region. Whereas paraplegia is a condition when a person has lost the sense of feeling and is not able to move the lower part of the body. Paraplegia occurred when the thoracic, lumbar or sacral region is injured. In addition to movement and feeling, spinal cord injury affects other bodily functions, such as breathing, and bowel and bladder control. Normal sexual functions may be impaired.

3.2 Cost of spinal injuries
Spinal injury may generate massive costs in hospital care, rehabilitation, personal or family grief and suffering. It may also lead to reduced employability. Furthermore, it is possible that patients with spinal injury may be forced to live out the remainder of their lives in institutional settings such as nursing homes for rehabilitation purposes. Marriages may also be affected by spinal injury. In fact in Malaysia and other developing countries, most motorcycle accident victims are in the youth group and may suffer many of these consequences if no intervention program is undertaken.

In general, spine injury is among the highest medical treatment cost due to longer hospitalization and rehabilitation period. The National Spinal Cord Injury Statistical Centre (NSCISC), University of Alabama, had calculated the cost of spinal cord injury distinct from other costs. It is interesting to note that when admission to the SCI system is delayed beyond a mere 24 hours, the length of stay and hospital charges for acute medical care and initial rehabilitation are higher.

Moreover, Zaloshnja et al. (2004) had calculated the crash costs by body part injured, fracture involvement, and threat-to-life severity in USA. Zaloshnja found out that the highest medical cost among other types of injury is neck-spinal cord injury; followed by
injury to trunk-spinal cord, brain, hips/thigh and skull fracture. The medical cost of neck-spinal cord non-fracture injury with MAIS5 is more than 80% higher than hips/thigh non-fracture injury with the same MAIS (Zaloshnja et al., 2004). Average yearly health care and living expenses that are directly attributed to SCI vary greatly according to severity of injury. High tetraplegia recorded the highest healthcare and living expenses followed by low tetraplegia, paraplegia and incomplete motor function injury (NSCISC, University of Alabama, 2008).

However, most of researchers only account for the cost of treatment of spinal cord injury without specifically discussing the cause of injury. It is far from considering the total cost of spinal injuries treatment incurs by motorcyclist crash victim. The author believes that the costs of spinal injury related to motorcycle crash are even higher if indirect and spill over factors such as permanent disabilities, loss of employment, and not to mention, the long term effects on the social economy of a nation are taken into consideration.

4 INJURY PATTERN AND MECHANISM

In general, the transition zones at the cervicothoracic and the thoracolumbar junctions are the most common segments of the spine to be injured. In United Kingdom and United States of America, motorcyclist has been found to be injured more commonly in the thoracic spine compare to cervical spine or lumbar spine (Robertson et al., 2002; Ankarath et al., 2002; Kupferschmid et al., 1989). In contrast, Asian countries such as Malaysia, Thailand and Taiwan recorded the highest frequency of cervical spinal injuries (Roohi et al., 2006; Ooi et al. 2005; Kasantikul et al., 2002; Kuo, 1996). However, across all the studies the injured victims were identical in which most of them were young male rider in the 21-30 age groups and most death occurred in riders under 40 years of age. Isolated spine injuries occurred in only about 30% whereas the rest suffer concomitant injuries.

Whilst, thoracic spine injuries account for most of the neurologic impairment, cervical spine injuries prove to be more fatal. More mortality was seen in cervical fractures than thoracic fractures (Ankarath et al., 2002). Typically lumbar region experience the lowest neurologic injuries and posed a minimal treat to lives. Therefore, it has been the least focus segment of spine to study compare to cervical and thoracic spine. Table 3 shows percentage of spinal injuries in three spinal segments from previous studies.

Table 3: Percentage of spine injuries in three spinal segments.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Total number of spine injuries</th>
<th>Spinal injuries by region (%)</th>
<th>Complete Neurological Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robertson et al., 2002</td>
<td>126</td>
<td>Cervical 22 (17.4)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thoracic 69 (54.8)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lumbar 37 (29.4)</td>
<td>1</td>
</tr>
<tr>
<td>Ankarath et al., 2002</td>
<td>129</td>
<td>Cervical 15 (11.6)</td>
<td>*2 paraplegia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thoracic 87 (67.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lumbar 17 (13.2)</td>
<td></td>
</tr>
<tr>
<td>Kupferschmid et al., 1989</td>
<td>19</td>
<td>Cervical 4 (21.1)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thoracic 13 (68.4)</td>
<td>8 paraplegia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lumbar 2 (10.5)</td>
<td>-</td>
</tr>
</tbody>
</table>
Mechanism of spine injury is complex and often involved numerous kinematics. However, Daffner et al., (1996) reports that spinal fractures occur according to predictable patterns with similar radiological changes seen after specific kinds of injuries. Based on Daffner et al. (1996) findings and existing body of literatures, Uwe Heimann and Michael Freund (2006) has categorized injury mechanism into four categories which are flexion injury, extension injury, rotation injury and shear injury. Each spinal segment’s injury patterns and its mechanism will be discussed in greater detail subsequently as there are numerous studies specific to each segment.

4.1 Cervical spinal injury

Ooi et al. (2005) found that motorcyclists sustained injuries to the lower parts of the cervical spine; C4, C5 and the intervertebral joint between C5-C6 were the most frequently injured location. Moreover, he found that when the cervical spine is divided into the upper cervical (occipital-antlanto joint to C3) and the lower cervical (C3-C4 to C7-T1), two frequently injured locations could be observed; C2 for the upper cervical region and C5 for the lower cervical. Similarly, a study by Robertson et al. (2002) mirrors the findings of Ooi et al. (2005), in that they found C5-C7 to be the most commonly injured area for cervical spinal injuries among motorcyclists.

The pattern shows that injuries mostly occurred to the skeletal part of the spine and it appears that soft tissue injury rarely occurs, but this could be due to the lack of case studies on such type of motorcycle accidents which are rather limited. Yet the study conducted by Kasantikul et al. (2003), utilizing a detailed layer-by-layer autopsy found that about one-third of motorcyclists who died in Thailand had significant soft tissue neck injuries. Their study indicates that soft tissue injuries to the neck region indeed occur among motorcyclists with spinal injuries but are often missed. They found that the most common and usually undiagnosed injuries were hemorrhage in the carotid sheath, subluxation in the occipital atlanto-axial complex, hemorrhage in the muscles and triangles of the anterior neck, or injury along the length of the vertebral artery. This corresponds to the earlier findings by Hurt et al. (1986). On the other hand, unlike the pattern found by Ooi et al. (2005) and Robertson et al. (2002), common skeletal injuries were found to occur more frequently at the upper cervical spinal area from the atro-occipital and C2-C3. Although soft tissue injuries such as occipital separation are usually found in relation to soft injuries to the neck, the sole cause of death is rarely attributed to such injuries but instead, often accompany head injuries as the primary cause of fatal injury to motorcyclists (Kasantikul et al., 2003).

4.1.1 Injury Mechanism

Cervical injury mechanism is intricate and not restricted to single kinematics upon crash. Thus, by classifying injury mechanism into certain predominant elements, Ooi et al. (2005) showed that flexion and extension were the most frequent injury mechanisms, experienced by motorcyclists in road crashes. The flexion mechanism occurs mostly on frontal impact while the extension occurred in the majority of rear end impacts. Lateral flexion caused most of the injuries sustained by riders who experienced side impact or skidding. Even though there may not be direct contact with the neck, the injury can be serious as neck injury severity increase as the Injury Severity Score (ISS) increases (Kasantikul et al., 2003).
4.2 Thoracic Spinal Injury

Robertson et al. (2002) reported that the most frequent thoracic spinal segment to be injured was T5 - T7. This is in agreement with earlier findings by Kupferschmid et al. (1989), Daffner et al. (1987) and Shrosbree et al. (1979) that found the area between T3-T8 as the most affected area. When the thoracic spine was divided into 3 regions, the most commonly affected area was found to be the mid thoracic spinal area. Table 4.2 summarizes the frequency of thoracic spinal injury occurrences in the three areas from existing literature.

Table 4.2: Frequency of injuries for upper and lower thoracic spinal area

<table>
<thead>
<tr>
<th>Reference</th>
<th>Total thoracic spinal injury cases</th>
<th>Upper thoracic injuries (T1-T4)</th>
<th>Mid-thoracic spinal injuries (T5-T8)</th>
<th>Lower thoracic injuries (T9-T12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robertson et al. (2002)</td>
<td>69</td>
<td>15</td>
<td>51</td>
<td>31</td>
</tr>
<tr>
<td>Kupferschmid et al. (1989)</td>
<td>13</td>
<td>9</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Daffner et al. (1987)</td>
<td>14</td>
<td>9</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

Lower thoracic spinal injuries in Robertson et al. (2002) are significantly higher than for other lower thoracic spinal injury studies because of the higher number of incidents of T12 injuries. The higher number of incidents of T11 – L2 (thoracolumbar spine) qualify it as the most common part to be injured in the thoracic spinal area after the mid-thoracic area.

Furthermore, thoracic spinal injuries are likely to cause severe neurological deficit. In the study by Kupferschmid et al. (1989), 62% of victims of thoracic spinal injuries had complete paraplegia while Shrosbree et al. (1979) reported that 81% of thoracic spinal injuries had complete neurologic deficit. The common neurological injuries occur mostly at the upper part of the thoracic spine (T1-T6) (Kupferschmid et al., 1989; Daffner et al., 1987). Correspondingly, Quinlan et al. (2005) found that 12 out of 15 motorcyclists who were injured in the upper thoracic spinal area suffered complete neurological deficit. This is because the thoracic spinal area has the narrowest spinal cord canal compared to the cervical spine (Denis 1983), making it particularly susceptible to injury from impingement at this area (Kupferschmid et al., 1989; Maiman et al., 1992).

However, the injury pattern described represented mostly those who had survived in many of the studies. These, however, represent only the injured victims rather than the total population of motorcycle crash victims including those who died on the spot. Moreover, so far, no data is available to elucidate the percentage of patients involved in thoracic spinal injury that included both who survived and those who died.

4.2 Injury Mechanism

Thoracic spinal injuries occur mostly in flexion and axial loading incidents because very little rotatory motion occurs in the upper thoracic spinal area as it strengthened by the rib cage (Bohman 1985). The injury mechanism often involves the victims being catapulted over the handlebars, after the motorcycle hits an object, striking the kyphotic curve of the thoracic spine (Kupferschmid et al., 1989; Daffner et al., 1987). Generally, thoracolumbar spinal injuries are usually caused by compression injuries (Denis 1983). However, the thoracolumbar injuries in motorcyclists may be attributed to another type of mechanism as shown by Heinemann and Freund (2006). According to Heinemann
and Freund (2006), rotation injuries occur primarily at the thoracolumbar junction as torsion rigidity is greatest at the T12-L1 segment. They show that a typical mechanism can be represented by a heavy blow to the shoulders which compresses the spine while the lower trunk is bent sideways and is twisted laterally. This mechanism is almost similar to the injury mechanism to the thoracic area described earlier- that which is caused by a person thrown off a motorcycle and crashing against a fixed or solid object.

4.3 Lumbar Spinal Injury
Lumbar spinal injury often will not lead to death, but it will make patients lose their working ability and affect the quality of their life. The most common segment of the lumbar spine affected in motorcycle crashes is L1-L2. This segment is often grouped together with the T11-T12 segment of the thoracic spine to form the thoracolumbar spine. Previous studies have repeatedly shown the thoracolumbar spine as one of most common segments of the spinal vertebra to be injured especially in those crashes involving high velocity injury (Stanislas et al. 1998). Although many studies have been done on thoracolumbar and lumbar injuries, so far there has been no specific research done to determine the lumbar spinal injury pattern and the exact mechanism leading to its occurrence in motorcycle crashes.

4.3.1 Injury Mechanism
There has been much research done about lumbar spinal injuries like drop experiments and computer simulations. Hsieh et al. (2007) studied the lumbar injury patterns of motorcyclists in 4 types of collision impacts using real impact force of traffic accidents to simulate the traffic crash. The study found that a different impact configuration yielded a different vertebral body fracture. For example in lateral impact, the spinal column undergoes compressive and postero-lateral bending, causing spinal encroachment at L1. Thus, spinal cord injury is likely in a crash involving lateral impact. Table 4.3 shows the findings by Hsieh et al. (2007)

Table 4.3: Impact simulation resulting in different vertebral body fracture (Hsieh et al. 2007)

<table>
<thead>
<tr>
<th>Burst fracture</th>
<th>Rear</th>
<th>Front</th>
<th>Lateral</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebral body</td>
<td>X</td>
<td>L1, L3</td>
<td>L1</td>
<td>L4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anterior wedge fracture</th>
<th>Rear</th>
<th>Front</th>
<th>Lateral</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebral body</td>
<td>X</td>
<td>L2, L4</td>
<td>L4</td>
<td>L1-L3, L5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pedicle base fracture</th>
<th>Rear</th>
<th>Front</th>
<th>Lateral</th>
<th>Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertebral body</td>
<td>X</td>
<td>L5</td>
<td>L5</td>
<td>L4</td>
</tr>
</tbody>
</table>

The study by Hsieh et al. (2007) provides good insight in demonstrating the mechanism of lumbar spinal injury patterns of motorcyclists but there have been no ‘real world’ case studies done on the lumbar spinal injury patterns of motorcyclists which can be compared or matched up.

The different pattern between the reviewed studies can be attributed to the different methods used in conducting the study. For example, Robertson et al. (2002) excluded brachial plexus injuries as part of the cervical injuries in his study. Furthermore, the difference also suggests that there is disparity of spine injuries among motorcyclists
between the country which normally uses motorcycles as leisure sports like United Kingdom and the country which extensively uses motorcycles as mode of transport like Malaysia. The size of most motorcycles in Malaysia and similar developing countries is smaller and more vulnerable as they swerve in and out of the traffic stream. Moreover, most of them do not wear protective clothing.

A study on injury outcome and its closely associated mechanisms are necessary to understand the relationship between their kinematics prior to the vehicle crash and injury outcome. A better understanding of these injuries and its mechanism will provide an immense assistance in improving proper diagnosis, treatment, and prevention.

5 INJURY TOLERANCE AND CRITERIA
Injury tolerances and criteria are a necessary foundation for the development of vehicle safety standards and in evaluating vehicle design for motorcycle safety. However, much of the effort has been directed towards the investigation injury tolerance criteria of the passenger car occupant. Over the years based on the experiments and tests that were performed the tolerance values for cervical response in extension, flexion, compression, tension and shear are well documented (Mertz and Patrick 1971; Goldsmith and Ommaya 1984; Maiman et al., 1983; Shea et al., 1991; Nightingale et al. 2007). Based on the tolerance values for neck loading established several neck injury criteria are proposed. Among the often used neck injury criteria are NIC (Bostrom et al., 1996), \(N_{ij}\) (Kleinberger et al., 1998), and \(N_{km}\) (Schmitt et al., 2001). NIC and \(N_{km}\) are developed to detect neck injuries in rear-end impact while \(N_{ij}\) was for frontal impact. To cover spinal soft tissue injuries Panjabi et al. (2005) proposed the Intervertebral Neck Injury Criterion (IV-NIC). Although, all the injury criteria developed enable to evaluate whiplash injury, motorcycle impact seldom involved whiplash-type injuries.

The data available on the tolerance of the thoracic and lumbar spine regions to injury are very limited. Cameron et al. (2008) have investigated thoracic and lumbar spinal impact on four cadaveric porcine specimens as a model for direct spinal impact injury to human beings. The average peak forces for thoracic failures are \(4720 \pm 1340\) N. From here, the estimated force for a 50% risk of injury on the human scale is approximately \(10,200 \pm 3900\) N.

To date, there is no injury criteria designed to investigate lumbar injuries. Most of the work is focused on stress analysis using finite element programmes. Shirazi et al. (1986) developed a non linear finite element programme to analyse lumbar motion for \(L_{3-4}\) in a strictly sagital plane. The finite model was further developed for the entire lumbar \(L_{1}-S_{1}\) in single flexion, extension and rotation motion (Shirazi 1994). The major finding of this model is its discovery that large tensile strains occur at disc fibres during flexion and lateral moment. This suggests the vulnerability of the disc fibre to fail under large flexion forces and lateral moments.

As the existing injury criteria are developed based on the passenger car and therefore restricted to conditions specified in their definition, successful application to other condition such as motorcycle crash are very dubious. A specific development of injury criteria for motorcycle crash is necessary. Furthermore, the use of anthropomorphic test device (ATD) can have some limitations for injury assessment as well. Currently, motorcycle anthropomorphic test device (MATD) is yet to have a good biofidelity and proper spine column.
6 CONCLUSION

Based on the present literature review, spinal injuries among motorcyclists are indeed prevalent and frequently cause devastating effects especially those involving spinal cord injuries. Spinal injuries should be accorded a high priority because of its enormous social burden and costs compared to other types of injury. The most critical part of the spine is the cervical due to the high mortality associated with cervical injuries. However, the thoracic spine is also critically important because injury to the thoracic spine often causes neurological deficit impairment and occurs in high frequency. This may reflect the need to have more rigorous patient assessment in motorcycle crash due to higher correlation between incidence of spinal injuries and multiple injuries which is common in motorcycle crash. Subsequently, with a better understanding of these injuries and its mechanism a proper diagnosis, treatment, and prevention will be enhanced.

Injury criteria for spine injury tolerance had been extensively explored for car safety evaluation. However, there are no injury criteria for spine injury related to motorcycle crashes yet. Without injury criteria, the severity of trauma in a crash test or an accident reconstruction cannot be evaluated. The development of more reliable injury criteria and model for injury prediction are therefore required for future evaluation of injury countermeasure. Also, it is recommended that studies on motorcycle crashes involving spinal injury model should include experimental tests to further improve our understanding of the mechanism of injury.

REFERENCES


AUTOMATED TRUCK PLATOONS ON MOTORWAYS –
A CONTRIBUTION TO THE SAFETY ON ROADS

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ABSTRACT
One opportunity to manage the rising freight transportation and to optimize the utilization of motorway capacities is the concept of truck platoons. With the aid of Advanced Driver Assistance Systems it is possible to couple trucks electronically. In consequence, trucks can keep short distances between vehicles of approx. 10 meters at 50 mph and that way realize truck platoons on motorways. Electronically coupled truck platoons offer various improvements to the freight transportation problem, such as improved vehicle occupancy, gained road space, optimization of traffic flow, reduction of fuel consumption due to slipstream driving, a relief for professional drivers and finally an increase in safety due to the longitudinal and lateral guidance. In this paper, a brief introduction to the technical background of these truck platoons is given, as they were realized and tested on public roads within the project KONVOI. The main focus is on the contribution to the road safety of electronically coupled trucks on German motorways. Hence, German accident statistics will be discussed and the benefit for the society due to accident reduction will be monetized and calculated on the basis of the German Federal Traffic Route Plan.

1 INTRODUCTION

1.1 Initial Situation
The integration of the new European member countries is a challenging component for national traffic planning in the near future. Especially countries with a central geographic position within Europe, such as Germany, have to shoulder the majority of the future traffic emergence. Due to the increase of global freight transportation, the maximum road capacity in several countries worldwide is nearly reached [ESCAP 2008]. Additionally, this traffic will predominantly encumber the road. A modern national economy needs an efficient traffic system to face such a challenge successfully. Otherwise, today’s even worse traffic situation will be pre-assigned to collapse.

The importance of efficient traffic systems was emphasized by studies from the European Commission in 2006. Between 1995 and 2004 a growth of 35% in European road freight transport was detected. Furthermore, between the years 2000 and 2020 an increase of 55% in road transportation is expected. In 2006 the road had to bear the majority of the cargo volume with 41% of all transport modes, besides rail traffic carried 8% of the volume. [CEC 2006]. Therefore, even small changes and improvements on road transportation will have large impacts. In the year 2003, the European Commission stated that every day 7,500 kilometers of the European road system are being blocked by traffic jams [CEC 2003]. Environmental pollution, safety risks and a loss in efficiency for the economy are only some of the effects
that result from growing volume of road traffic. Similar problems are known and discussed in industrial nations worldwide.

One possibility to face the rising traffic volume on the roads is the modal shift to other types of transportation (e.g. rail, shipping). Another opportunity is the optimization of the road-side traffic flow by driving assistance systems. In the future, such systems could perform tasks which currently have to be executed manually by the truck driver. Since the 90s, Advanced Driver Assistance Systems (ADAS) for trucks have been on offer, including pre-adjustment of speed and distance to the front vehicle. This is exerted automatically via computerized engine- and brake-management in connection with an automated transmission. The combination of an Adaptive Cruise Control (ACC) together with an Automatic Guidance (AG) leads to autonomous driving.

The difference in this context is the necessity of a leading vehicle. Following trucks can go far distances without any manual engagement by the driver as long as another ahead-driving vehicle exists. Nevertheless, each truck must be assigned with a truck driver at all times due to legal rules and regulations.

Within platoons, smaller distances between the vehicles (up to 10 meters) can be realized. These truck platoons contribute to an optimization of traffic flow up to 9% and a reduction of fuel consumption up to 10% due to slipstream driving [Savelsberg 2005].

The development and evaluation of the practical use of truck platoons is the objective of the project KONVOI, which was funded by German’s Federal Ministry of Economics and Technology. KONVOI is based on the scenario “Platoons Organized by the Driver” (Figure 2) which was developed in the project “Operation-Scenarios for Advanced Driving Assistance Systems in Freight Transportation and Their Validation” (EFAS) [Henning 2003]. The Project KONVOI was an interdisciplinary research project with partners of RWTH Aachen University, industry and public institutions, which ended after a duration of 49 months with test runs on German motorways at the end of May 2009 (Figure 1). With the assistance of virtual and practical driving tests by using experimental vehicles and a truck driving simulator, the consequences and effects on the human-, the organization- and the technology-dimension have been analyzed [Henning et al. 2007].

![Figure 1: Test Run on German Motorways (March 2009)](image)

1.2 Problem Definition
The electronic coupling of trucks within the project KONVOI offers a bundle of advantages, such as a reduction of the inter-vehicle distance, which leads to an improved vehicle occupancy and gained road space, an optimization of traffic flow, the reduction of fuel consumption advantaged by slipstream driving, a relief for professional drivers, and finally an increase in road safety due to the longitudinal and lateral guidance.
This paper focuses on the question, what monetized contribution to the safety on roads can be expected due to the longitudinal and lateral guidance of electronically coupled trucks. Therefore, within the next chapters the scenario of “Platoons Organized by the Driver” as well as the platoon system is described in detail. Afterwards the effects of the electronic coupling on the German accident statistics will be discussed. Finally, the benefit of the changes of accident rates will be calculated based on the Bundesverkehrswegeplan (BVWP - German Federal Traffic Route Plan) [BMVBS 2005].

2 ELECTRONICALLY COUPLED TRUCKS

2.1 The Scenario “Platoon Organized by the Driver”

The scenario “Platoons Organized by the Driver” (Figure 2) was developed in the project “Operation-Scenarios for Advanced Driving Assistance Systems in Freight Transportation and Their Validation” (EFAS). Further scenarios within the project EFAS were the “centrally organized platoons” and the “platoons on a special truck lane”. All three scenarios were evaluated in consideration of the categories human (stress, acceptance), environment (fuel consumption, noxious emission) and traffic (temporal distance, velocity, acceleration, collision time, journey time, traffic flow and volume). Additionally, legal aspects were taken under consideration. The evaluation of these scenarios showed that the first scenario offers the best possibility for a medium-term implementation with some necessary modifications [Henning 2003].

In the scenario “platoons organized by the driver”, the platoons can operate on today’s existing motorways without extending the infrastructure. The driver has the permanent control of the autonomous driving procedures [Henning 2003]. The creation of a platoon depends on the initiating driver who delivers the necessary data about time and place of meeting, the destination of his tour, as well as the required truck telemetric data (loading weight, engine power etc.) with the help of a Driver Information System (DIS). The high flexibility of truck transportation is not lost, because scheduling, like in rail traffic, is dispensable.

After activating the ADAS, a selection of the best matching platoons is automatically shown. The ADAS informs the driver and prepares the participation to the selected platoon. The DIS acts as a human machine interface of the platoon system and helps the truck driver to plan the route and guides the driver to the meeting point [Friedrichs 2008a].

The driver has to initialize and respectively confirm all of the platoon manoeuvres in order to build and to dissolve the platoon. As soon as the final position in the platoon is reached, an automated longitudinal guidance with a target distance of 10 meters between the trucks and a lateral guidance is possible. On one hand, this target distance was chosen because the short distance prevents most drivers from driving in the gaps between the platoon members. On the other hand, the short distance causes slipstream effects, which can lead to reduced fuel consumption.

Since road markings are needed for the lateral guidance, the platoon system is exclusively developed for the use on motorways. Because of a speed limitation for most trucks at approx. 50 mph, the speed of the trucks on motorways differs only slightly. Therefore, the truck platoons are operating at a speed between 37 and 50 mph. This speed can be managed safely at 10 meters distance by the KONVOI-System.
2.2 The Platoon System
In order to realize different platoon sizes, the consortium of the project KONVOI equipped four experimental vehicles with the required automation-, information- and automotive-technology (Figure 3). The main components for the implementation of the system architecture in the experimental vehicles are the actuators (steering and power train), the sensors (object registration in close-up and far range, recognition of lane), the vehicle-vehicle-communication (WLAN), the automation unit (coordination of the different vehicle states), the control unit (longitudinal and lateral guidance) and the driver information system (human-machine interface, organization assistant, GPS and 3G) [Henning 2007].

The longitudinal guidance of the ADAS is based on a LIDAR (Light Detection and Ranging) distance sensor, a Complementary Metal Oxide Semiconductor (CMOS) Camera and a RADAR-sensor. The distance sensors are used to determine the distance in longitudinal direction and the lateral offset to the leading vehicle. The vehicle-vehicle-communication transfers necessary vehicle CAN-bus-data from all platoon members, which are required for the longitudinal guidance to realize the target distance of 10 meters. In all trucks, a target acceleration interface is implemented, which automatically calculates the drive-train and the management of the different brakes in the vehicles. The acceleration is either calculated autonomously for each vehicle or deduced from the data which is transferred via the vehicle-to-vehicle-communication.
Every experimental vehicle is attached with cameras which are able to identify the traffic lane, thus determining the position of the truck within the traffic lane. An electronically accessible steering system has been integrated additionally. A steering actuator on the base of an electric motor delivers the necessary steering moment for the automated guidance of the trucks [Friedrichs 2008].

With the help of the Driver Information System, the truck driver plans his route, selects economic platoon participants as well as initializes and respectively confirms the platoon manoeuvres in order to build and to dissolve the platoon. The platoon organization is realized on a central server with a data-mining algorithm under consideration of economic aspects [Meisen 2008]. For this task, the DIS has to send the time schedule, route plan and GPS position of the truck with a vehicle infrastructure-communication via G3 to the central server (Figure 4).
3 CONTRIBUTION TO THE SAFETY ON ROADS

3.1 Accidents on German Motorways
On German motorways all accidents of personal injuries and heavy damages to property are registered by police. This data is prepared and published by the German federal statistical office on an annual basis [Statistisches Bundesamt 2007].

In the year 2007 the majority of all accidents are induced due to rear-end crashes with stopping or moving vehicles (44% of all accidents). Running off the side of road is the second and side crashes with other vehicles the third most common cause for accidents. Freight Transportation is responsible for 52% of all accidents on German Motorways. 21% of all accidents on German motorways are rear-end accidents caused by freight transports [Statistisches Bundesamt 2007].

Hence, Advanced Driver Assistance Systems, which inherit longitudinal and lateral driving tasks, and which monitor the environment of a vehicle, have a tremendous potential for accident avoidance. A longitudinal and lateral guidance is already implemented in the KONVOI system for lane and distance keeping. During a KONVOI-ride, the following vehicles in a KONVOI-platoon will not be able to cause an accident by tailgating or running off the side of a motorway. Therefore, the usage of the KONVOI-system itself is a contribution to the safety on roads.

The KONVOI-system has been developed, to support the driver and therefore take over driving operation to keep the distance between vehicles and to keep the vehicle within the road markings. During the project KONVOI a bundle of consolidated findings could be gathered. For example, analysis of the driving procedure showed that the design of the truck driver’s workplace has to be reconsidered. The prerequisite, operations of the KONVOI-system as well as the manual take over through the driver must be guaranteed at all times, should be ensured technical-wise. Hence, the KONVOI-system could be supplemented by systems which control the driver’s attention, such as a head and eye movement detection or a dead man’s control, which is known from railways. A fundamental further development of the KONVOI-system could be the Collision Avoidance (CA). The LIDAR- and RADAR-sensor as well as the image processing systems for the CMOS-camera picture are already implemented in the experimental trucks and could be used to monitor the environment of the vehicle and interpret the surroundings concerning potential hazardous situations. Especially the longitudinal guidance could be adapted easily, because changes have to take place software-wise and generally not on hardware. With these changes, the KONVOI-system would exploit further potential for the collision avoidance.

Lammen (1993) already mentioned, that systems for the electronic coupling of vehicles would reduce the risk of accidents, independently, if the vehicle is part of an electronically coupled platoon or not. Thus, the likelihood for the avoidance of accidents is dependable on the equipment rate of Advanced Driver Assistance Systems and not dependable on the utilization rate of the KONVOI-System. The key question, which has to be answered for further considerations, is, how high the accident avoidance potential of the electronic coupling could be estimated.

The Institute for Automotive Engineering Aachen (ika) accomplished research activity in the field of accident avoidance of passenger cars on behalf of the German Ministry of Transport, but research results have not been published [Bauer 2008]. Additionally, neither empirical data of the accident reduction through driver assistance systems of transport vehicle are available. Therefore, the accident avoidance potential of the ADAS for the electronic coupling has to be estimated carefully for further considerations.

As mentioned above, in 2007 freight transportation caused 21% of rear-end accidents on German highways. A conservative accident avoidance potential of over 50% for rear-end
accidents on motorways is estimated, which are caused by freight transportation and can be led back to too short distances between vehicles. Therefore, a reduction of more than 10% for all rear-end accident of freight transportation can be estimated. For accidents with casualty and trucks of more than 12 tons Kitterer (2006) calculates an accident avoidance potential of 12% due to the application of driver assistance systems. In the following considerations a total accident avoidance potential of 10% for all accidents will be assumed. An increased risk for further road users shall be excluded [Neunzig 2003].

3.2 Evaluation of the Safety Benefit

Any accident has a variety of effects, which should not be underestimated. An accident may have tragic and fatal consequences for the individuals involved. A possible decrease or loss of the social contribution to the national economy can be another effect. In this paper the view of the safety benefit will concentrate on financial aspects, which are used and predefined by the German Federal Ministry of Transport, Building and Urban Affairs.

The evaluation of the accident avoidance potential of Advanced Driver Assistant Systems as well as the calculation of the benefit of the accident avoidance potential for trucks will be based on the German “Bundesverkehrswegeplan (BVWP)”’. The BVWP is used by the German Federal Ministry of Transport, Building and Urban Affairs [BMVBS 2005] and has the overall goal, to enhance the welfare of the German population [IVV 2000]. Within the BVWP all variables for the effects on road safety are taken into account, such as the likelihood for accidents and the severity of accidents.

Figure 5 explains the calculation scheme for the change of road safety [BMVBS 2005]. The benefit of the increase in traffic safety will be expressed by the variable NS (see Figure 5). In this calculation all accidents with casualties and accidents of property are distinguished (Index PS and SS). Therefore, all accident risks for all routes will be calculated and transformed into accidents rates (accidents/10^6 vehicle-km). The estimated rates of the BVWP for the traffic accidents with casualties are presented in Figure 6, the rates for traffic accidents of property are displayed in Figure 7. For the calculation of the benefit of electronically coupled trucks on motorways, just the highlighted rates will be needed, because they represent accidents on motorways.

An evaluation based on the BVWP requires a comparison of a so called comparable case and a future case, whereas the future case includes all investments, which have to be evaluated. In this paper the future case will take place in 2015. All input quantities will be chosen, so that the effect of truck platoons for the entire vehicle collective on highways in the year 2015 can be determined. Therefore all physical units will be identified and after that monetized. The reference year 2015 was chosen, because all effects of the Driver Assistance Systems of a realized KONVOI-system can be estimated at that point of time.

At the reference your 2015 27,544 accidents of personal injuries and 180,934 accidents to property will occurred. Due to the assumptions of an accident avoidance potential of 10%, the accidents with casualty would be reduced to 24,790 and the accidents to property would amount to 162,841. The total accident avoidance potential for the reference year will be 20,848 accidents [Gresser (2001), Brandt (2008)].

This data is required for the calculation of road safety. But furthermore more information is needed, such as the length and index of road sections (see Figure 5), which will be gathered by simulation.
\[ NS = \sum_{i} (UK \ast l)_{vg} - \sum_{i} (UK \ast l)_{pl} \]

with

\[ UK = \left( UR_{PS} \ast DTV_{ges} \ast UKS_{PS} + UR_{SS} \ast DTV_{ges} \ast UKS_{SS} \right) \ast \frac{365}{10^6} \]

\[ DTV_{ges} = \frac{4824 \ast DTV_u + 2424 \ast DTV_u + 1512 \ast DTV_s}{8760} \]

NS [€/a]: Benefit of the Road Safety Contribution
i: Index of Road Section
l [km]: Length of Road Section
UK [€/km*a]: Length Related Accident Costs of a Road Section
UR_{PS} [U/106*Kfz*km]: Accident Rates of Accidents of the Damage to Persons depending on Road Types
UR_{SS} [U/106*Kfz*km]: Accident Rates of Accidents of the Damage to Property depending on Road Types
UKS_{PS} [€/U]: Accident Expense Ratio of Accidents of the Damage to Persons depending on Road Types
UKS_{SS} [€/U]: Accident Expense Ratio of Accidents of the Damage to Property depending on Road Types
DTV_{ges} [Kfz/24h]: Total Average Traffic of a Road Section considered all Days of the Year (8.760 h)
DTV_u [Kfz/24h]: Average Traffic of a Road Section considered all Work Days of the Year (4.824 h)
DTV_s [Kfz/24h]: Total Average Traffic of a Road Section considered all Work Holidays of the Year (2.424 h)
DTV_S [Kfz/24h]: Total Average Traffic of a Road Section considered all Sunday and Holiday of the Year (1.512 h)
vg: Index of Comparative Case
pl: Index of Plan Case

Figure 5: Calculation Scheme for the Change of Road Safety [BMVBS 2005]

Figure 6: Accident Rates for Road Accidents of the Damage to Persons depending on Road Types regarding the German Federal Transport Network Plan (BVWP) [BMVBS 2005]
Profitability calculations of road investments are based on models, which contain an image of the real world with all key valuation-related components. For an analysis of the profitability with the BVWP different related route data and traffic data are necessary, which have to be pictured in this model. In detail, these data are route type, route length, speed limits, slopes, and curviness (route data) as well as average daily traffic, proportion of freight transport respectively for work days, holidays, and weekends (traffic data). For calculations of the profitability the net model NEMOBFStr98 is used, in which all route and traffic related data are assigned. The NEMOBFStr98 is owned by the German Federal Ministry of Transport, Building and Urban Affairs and has been applied to the planning of the federal highways. The entire net consists of 6.313 motorway parts with a total length of 12.927,76 km.

The model is applied to simulations and calculations in accordance with the BVWP. In this paper only the benefit for road safety is put in focus, which could be calculated through the model. The benefit of the road safety consists of the changes of the accident rates for road accidents with personal injuries and the changes of the accident rates of property damage. The reduction of the number of accidents with personal injuries reveals a benefit of 188 Mio. € per year. The monetized benefit of property damage sums up to 240 Mio. € per year. Hence, the road safety contribution of Advanced Driver Assistant Systems for the electronically coupling of trucks amounts 428 Mio. € per year.

4 CONCLUSION

Due to the application of the German Federal Traffic Route Plan on the electronic coupling of trucks, the contribution to the safety on roads of these trucks could be analyzed. The changes
of the rates of accidents have been calculated. Accidents with personal injuries as well as accidents of property damage have been taken into account.

A profound estimation of the German accident statistics shows that the realization of Advanced Driver Assistance Systems on German motorways, such as the longitudinal and lateral guidance, can avoid 10% of all accidents on these motorways. The total monetized contribution to the road safety in this case amounts 428 Mio. € per year. Due to this saving potential and the reduction of direct effects of accidents, obligations for Advanced Driver Assistance Systems are desirable. Any truck itself, which is equipped with a KONVOI-System and drives electronically coupled in a truck platoon, provides a small contribution to the road safety due to the realized accident avoidance.

This paper shows the positive influence of technical system for the avoidance of accidents, focusing on the direct consequences and effects due to the automatic control. Nevertheless, further questions regarding the application of Advanced Driver Assistance Systems have to be answered. In the future, indirect consequences and effects, e.g. the effects of the automatic guidance on professional truck drivers, will be considered and investigated.

REFERENCES


MOBILE TRAFFIC SAFETY INTEGRATION WITH OFF BOARD NAVIGATION - MOTION.

Evaluation of acceptance and traffic safety with a Speed Alert function.

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2 VTI, Sweden
3 TRIONA, Sweden

ABSTRACT

A six month national Field Operational Test (FOT) with more than 1 100 drivers using a Speed Alert function integrated in GPS-equipped cellular phones has been conducted in Sweden. Focus of the FOT was to study how a Speed Alert system should be designed to achieve as high acceptance as possible of the individual users. This differs this study from earlier studies on Speed alert or ISA that has primarily focused on speed reduction on the cost of acceptance. The drivers have been logged and interviewed with regard to their use, acceptance and experience of the system. From the study conclusions about traffic safety effects and implementation strategies are drawn. The field trial ended July 31st and results will be presented at the conference.

KEYWORDS

Speed management, Speed Alert, ISA, Acceptance
INTRODUCTION
Driving too fast is one major cause to accidents (see eg (Finch, Kompfner et al. 1994; Wheeler and Taylor 2000; Nilsson 2004). A number of projects have come to the result that Speed Alert-functionality can help drivers not to exceed current speed limits and drive more safe (Carsten and Fowkes 2000; Biding and Lind 2002; Hjalmdahl and Varhelyi 2004; Varhelyi, Hjalmdahl et al. 2004; Almqvist 2006; Brouwer and Hoedemaeker 2006). One major obstacle for the use of Speed Alert, by private car drivers, has been the cost of a new device to host the software but also the fact that most drivers are not interested in the systems or even negative to them, this is especially evident for the prone speeders who would benefit the most from the system (Falk, Hjälmdahl et al. 2002; Hjälmdahl 2004).
To try and make the system more attractive to the general population the Speed Alert system tested in this project allows the user to set when he should be warned (how much over the speed limit) and how (information only, visual or visual + audio warning).
The solution to decrease the cost is to integrate Speed Alert with navigation and other services and use the same device for all services. In this project an existing commercial offboard navigation system where the client application is running on mobile phones has been used. The use of mobile phones as clients enables a much broader user group for Speed Alert than traditional “ISA-systems” and it allows for a data supply chain that enables up-to-date information.

Scope
The results in this paper comes from the research project MOTION where the focus has been to find a way to reach a large amount of users of a Speed Alert service. To reach usual drivers we need to integrate Speed Alert with commercial and well known Navigation-services. To enable a large amount of users, user uptake has been in focus in MOTION. We need to know how Speed Alert should work to attract the drivers.
Effects on traffic safety and if the drivers drive slower and more safely, by using the Speed Alert service, has not been in focus in MOTION. A number of other projects have already studied that (Brookhuis and de Waard 1999; Carsten and Fowkes 2000; Biding and Lind 2002; Hjälmdahl 2004; Varhelyi, Hjalmdahl et al. 2004; Almqvist 2006).

SYSTEM DESCRIPTION
Speed Alert was introduced as a feature in two commercial navigation systems for mobile phonens that offered the test pilots the possibility to see the posted speed limit and get a warning (configurable in terms of how and when to warn) when speeding within Sweden.
Speed Alert is based on speed limit data located in the National Road Database, NVDB, for which the Swedish Road Administration has responsibility.
As soon as the user has installed the software in their mobile phones and the GPS receiver has a fixed position, Speed Alert will warn the user when speeding even if the user does not have a navigation session running (i.e. even from the main menu of the application). As default, Speed Alert is configured to warn the user both visually (large blinking speed sign with the posted speed limit) and auditory (pulsing warning sound).

The Speed Alert function is configured by entering “Inställningar – Hastighetsvarningar”. Here the user is offered the possibility to configure HOW the system will alert when the posted speed limit is passed:
• No warning at all and just show the posted speed limit as a small icon in the navigation view

• Visual warning (large blinking speed sign) for as long as the vehicle is moving faster than the speed limit or until the user chooses to cancel the warning manually (cancellation of the Speed Alert warning function until reaching a road with a different speed limit, which will automatically reactivate the system)

• Auditory (warning sound pulse) AND visual warning (large blinking speed sign) for as long as the vehicle is moving faster than the speed limit or until the user chooses to cancel the warning manually (cancellation of the Speed Alert warning function until reaching a road with a different speed limit, which will automatically reactivate the system)

It is also possible to configure WHEN, the system will alert you, by specifying a difference between the vehicle speed and the posted speed limit (an offset) in the interval of -5km/h (which will warn 5km/h below the posted speed limit) to +30km/h (which will warn when the vehicle is moving 30km/h above the posted speed limit).

The default settings is that the system warns (both auditory and visually) when passing the exact posted speed limit.

The posted speed limit is always shown in the navigation view as long as there is a GPS fix and the system is successful in identifying the posted speed limit.

![Figure 1 – Possible settings, Auditory or not, offset and speed camera warning](image)

**METHOD**

A major field test started in March and ended in August 2009. Data from around 650 test pilots was collected. Focus has been on how the drivers want to configure their Speed Alert-functionality to really use it and feel comfortable with the system.
Test pilots
The test pilots were recruited from existing users of two separate commercial navigation systems developed by one of the project partners (APELLO) as well as from the general public. Since the test-pilots used their own hardware (mobile phones) and catered for the software download and installation themselves there was no need for any inclusion or exclusion criteria, instead as many test pilots as possible was sought after. In March 2009, all current users of the navigation systems got an SMS offering them to become test pilots. In addition VTI sent out a press release describing the upcoming field test. To be able to download the software the drivers had to fill in a recruitment questionnaire. In total 1328 recruitment questionnaires were completed and log data from 962 test pilots were recorded. Taken together 657 test pilots had both answered the recruitment questionnaire and had log data recorded from their drives. Exactly 4 weeks after activating the client application, the driver got an SMS, asking him/her to complete a second questionnaire. Among these 657 test pilots 237 completed the 4-weeks questionnaire. A request to answer an end questionnaire was sent out to drivers that had activated the client application before the first of June and had log data from July. Only 45 test pilots completed the end questionnaire. All of the following analyses are based on the 657 test pilots for whom we have both questionnaire data and log data. For these 657 test pilots data from the one-month questionnaire have also been used while data from the end questionnaire have been excluded due to the low response rate.

The 657 test pilots’ age ranged from 18 to 81 years, with a mean age of 47 years. 96% of the test pilots were men while 4% were women. On average the test pilots had their driving licence for 27 years and 58% of them had driven 20 000 km or more during the previous year. 69% of the test pilots lived in communities with less than 100 000 inhabitants and their most common drive was to and from their workplace. 69% stated that they were very interested in technology and 97% had previously tried a navigation system while 40% had tried a Speed Alert/ISA-system.

Experimental design
The technology used in this FOT incurred some limitations on the experimental design, especially for the log data. Since the Speed Alert system had to be switched on for the data logging to start it was not possible to study how the drivers drove with the system switched off, similarly it was not possible to ask the drivers to download the system, turn it on to log data without having the Speed Alert function activated. Thus, neither a with/without or before/after design was possible in this study. On the other hand, focus was not on how the system affected speed and driving behavior, instead focus was on how the drivers used the system and if they accepted it.

To be able to make up to some degree for not logging “non-usage” data, questionnaires that covered both self estimated change in driver behavior and acceptance issues was used. The questionnaires were issued before downloading and after four weeks use.

Surveys
The test pilots were asked to complete three web questionnaires. The recruitment questionnaire had to be completed before the test pilots could download the application to their mobile phones. This questionnaire mainly included demographic questions such as age, gender, years holding a driving licence, mileage etc. Exactly four weeks after activating the application a request to answer a new questionnaire was send out. At the end of the trials all drivers who had activated the application before the first of June and had log data recorded in July, received an SMS inviting them to complete an end questionnaire. These two
questionnaires included questions about the application and how it affected the test pilots driving. Due to the low response rate the end questionnaire was however excluded from further analyses.

**Log data**

For each driving session where Speed Alert was activated a number of parameters were logged. The parameters are given in Table 1. A new session begins each time Speed Alert is started and also each time any of the settings are changed.

<table>
<thead>
<tr>
<th>Table 1 - Data that was logged in each driving session.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session id</strong></td>
</tr>
<tr>
<td><strong>Customer id</strong></td>
</tr>
<tr>
<td><strong>User id</strong></td>
</tr>
<tr>
<td><strong>Client platform</strong></td>
</tr>
<tr>
<td><strong>Settings:</strong></td>
</tr>
<tr>
<td><strong>Settings:</strong></td>
</tr>
<tr>
<td><strong>Start position</strong></td>
</tr>
<tr>
<td><strong>End position</strong></td>
</tr>
<tr>
<td><strong>Start time</strong></td>
</tr>
<tr>
<td><strong>End time</strong></td>
</tr>
<tr>
<td><strong>Max speed</strong></td>
</tr>
<tr>
<td><strong>Mean speed</strong></td>
</tr>
<tr>
<td><strong>Distance driven per relative speed and speed limits</strong></td>
</tr>
</tbody>
</table>

**RESULTS**

**Usage**

As mentioned above in 0 Test pilots, 69% of the test pilots stated that they were very interested in technology and 97% of them had previously tried a navigation system while 40% had tried a Speed Alert/ISA-system.

Table 2 shows that the test pilots’ main reason for wanting to try Speed Alert was comfort (e.g. always knowing the speed limit) and after downloading the application comfort was also the main reason for using Speed Alert.

<table>
<thead>
<tr>
<th>Table 2 - The test pilots’ main reasons for wanting to try and use Speed Alert, respectively.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comfort</strong></td>
</tr>
</tbody>
</table>

---
WHAT IS YOUR MAIN REASON FOR WANTING TO TRY SPEED ALERT?

N=657

<table>
<thead>
<tr>
<th>Reason</th>
<th>兴趣</th>
<th>安全</th>
<th>罚款</th>
<th>环境</th>
<th>合计</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your main reason for wanting to try Speed Alert?</td>
<td>44.0</td>
<td>22.1</td>
<td>12.9</td>
<td>12.3</td>
<td>8.1</td>
</tr>
</tbody>
</table>

WHAT IS YOUR MAIN REASON FOR USING SPEED ALERT?

N=233

<table>
<thead>
<tr>
<th>Reason</th>
<th>兴趣</th>
<th>安全</th>
<th>罚款</th>
<th>环境</th>
<th>合计</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is your main reason for using Speed Alert?</td>
<td>49.4</td>
<td>16.7</td>
<td>10.3</td>
<td>15.0</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Among the test pilots who answered the one-month questionnaire 94% thought that installing Speed Alert went well and after installation they estimated that they drove with Speed Alert activated for an average of 49% of the time. The most common reason for not having Speed Alert activated was “other” (34%) followed by “sometimes forgetting to start the program” (26%), “not always having time to start the program” (20%), “not always having the mobile with me” (9%), “not needing Speed Alert” (6%) and “thinking that Speed Alert does not work satisfactorily” (5%).

Most test pilots drove with the mobile mounted in the car with hands-free (41%) followed by mounted in the car without hands-free (32%), not mounted in the car without hands-free (16%) and finally not mounted in the car with hands-free (11%).

The test pilots used Speed Alert most frequently on private- and business trips outside their home community while they use the application least frequently to and from work as well as on business trips within their home community, Table 3. With regards to the traffic environment the test pilots used Speed Alert most frequently in environments unknown to themselves and on rural roads while they used the application least frequently in environments they knew well and in urban traffic, Table 4.

Table 3 - Mean and standard deviation for use of Speed Alert on different types of trips. N=165-231

<table>
<thead>
<tr>
<th>Type of trip</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other private trips outside the community</td>
<td>2.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Business trips outside the community</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Other</td>
<td>2.1</td>
<td>1.2</td>
</tr>
<tr>
<td>Other private trips within the community</td>
<td>1.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Business trips within the community</td>
<td>1.6</td>
<td>1.3</td>
</tr>
<tr>
<td>To and from work</td>
<td>1.5</td>
<td>1.4</td>
</tr>
</tbody>
</table>

0= never; 4=always

Table 4 - Mean and standard deviation for use of Speed Alert in different types of traffic environments. N=154-233

<table>
<thead>
<tr>
<th>Type of traffic environment</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>In unknown traffic environments</td>
<td>3.1</td>
<td>0.9</td>
</tr>
<tr>
<td>On rural roads</td>
<td>2.9</td>
<td>0.8</td>
</tr>
<tr>
<td>On motorways</td>
<td>2.7</td>
<td>1.1</td>
</tr>
<tr>
<td>When I’m alone in the car</td>
<td>2.7</td>
<td>0.8</td>
</tr>
<tr>
<td>When I have passengers</td>
<td>2.5</td>
<td>0.9</td>
</tr>
<tr>
<td>In urban traffic</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>In well known traffic environments</td>
<td>2.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

0= never; 4=always
Functionality

Among the test pilots who answered the one-month questionnaire a majority (73%) most frequently used Speed Alert in Navigation mode, which they also thought was the mode in which Speed Alert functioned best.

Table 5 shows that the test pilots thought that the visual information about their own driving speed, the speed limits and the warnings (when speeding) were important, informative and clear. At the same time, they thought that the auditory warning (for speeding) was clear but somewhat less important and informative.

Table 5 also shows that the test pilots thought that all the visual information was somewhat too small. At the same time, a clear majority of the test pilots (71% and 70%, respectively) stated that they never or very rarely had had any problems seeing the visual information given about their own driving speed or about the speed limits.

Table 5 - The test pilots’ opinions of the information given by Speed Alert. N=194-234

<table>
<thead>
<tr>
<th>Information about:</th>
<th>Important (0)</th>
<th>Unimportant (4)</th>
<th>Informative (0)</th>
<th>Confusing (4)</th>
<th>Clear (0)</th>
<th>Unclear (4)</th>
<th>Too large (0)</th>
<th>Too small (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your own speed</td>
<td>0.6</td>
<td>0.3</td>
<td>0.7</td>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.7)</td>
<td>(0.5)</td>
<td>(0.9)</td>
<td>(0.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The speed limit</td>
<td>0.4</td>
<td>0.3</td>
<td>0.6</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(0.5)</td>
<td>(0.8)</td>
<td>(0.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeding - visual</td>
<td>0.6</td>
<td>0.4</td>
<td>0.3</td>
<td>1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.7)</td>
<td>(0.6)</td>
<td>(0.6)</td>
<td>(0.6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speeding - auditory</td>
<td>1.2</td>
<td>1.1</td>
<td>0.7</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.0)</td>
<td>(1.2)</td>
<td>(1.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard deviations given within brackets.

In Speed Alert it is possible for the test pilots to decide how and when the warnings for exceeding the speed limits should be given. In the current project 90% of the test pilots changed the settings for both how and when the warnings should be given (the default setting was visual plus auditory warnings at the speed limit). With regards to how the warnings should be given, visual plus auditory warnings (58%) was the most popular choice followed by only visual warnings (40%). According to both questionnaire- and log data a majority of the test pilots choose to get the warning at the speed limit or up to 10 km/h above it, see Figure 2.
The figure above shows that the drivers have changed the level where they want warnings to occur from the default “0” to “5” and “10” km/h above the speed limit in many cases.

The figure above shows the selected warning offset per user (as an average over the total distance driven). It can be seen that drivers who often exceed the speed limit tend to select a larger warning offset.
In general, 93% of the test pilots thought that Speed Alert was very or quite good. 69% also stated that they had a great trust in the speed warnings given, even though 46% of the test pilots sometimes had received faulty information about the speed limits. 34% of the test pilots were not willing to pay anything extra to get Speed Alert while the rest of them were willing to pay an average of 12 SEK (ranging from 0-99 SEK) per moths for the application.

**Effects**

According to the log data the average test pilot drove just over 1 000 km with Speed Alert activated, and 43% of the distance was spent above the speed limits. Figure 4 shows the speed distribution, in 5 km/h intervals relative to the speed limits.

![Figure 4 - Distance driven per speed interval relative to the speed limits (data from 657 users).](image)

According to the test pilots they spent statistical significantly (p<0.001) less time exceeding the speed limits with 5 km/h or more when they had Speed Alert activated compared to before they downloaded the application, see Figure 5.
With regards to exceeding the speed limits the test pilots thought that there are a strong relationship between speed and the risk of accident involvement, Table 6.

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a strong relationship between speed and the risk of accident involvement</td>
<td>-1.4</td>
<td>0.8</td>
</tr>
<tr>
<td>It is more important for me to follow the traffic flow than to comply with the speed limits</td>
<td>-0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>It is stressful for me to comply with the speed limits</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Drivers who always comply the speed limits creates queues and irritation</td>
<td>0.1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

- 2 = completely agree; 2 = completely disagree

Once the test pilots had tried Speed Alert they thought that their petrol consumption and irritation decreased less than expected with Speed Alert and that the joy of driving had increased less than expected, Table 7.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Expectations before downloading Speed Alert</th>
<th>Expectations of driving with Speed Alert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your petrol consumption</td>
<td>-0.7 ***</td>
<td>-0.4</td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(0.5)</td>
</tr>
<tr>
<td>Your irritation</td>
<td>-0.6 ***</td>
<td>-0.3 ***</td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(0.6)</td>
</tr>
<tr>
<td>Your driving speed</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
<tr>
<td></td>
<td>(0.6)</td>
<td>(0.6)</td>
</tr>
<tr>
<td>Your travel times</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>(0.4)</td>
<td>(0.5)</td>
</tr>
</tbody>
</table>
With regards to other aspects of driving (e.g., attention, effort, frustration, time pressure, feeling of being in the way, acceleration/deceleration and frequency of looking at the speedometer) the test pilots did not feel any difference when driving with Speed Alert compared with driving without the application. At the same time, 93% of the test pilots thought that Speed Alert made them much better or better drivers.

### DISCUSSION AND CONCLUSIONS

One of the main aims of the project was to study how and when the drivers wanted to be warned and how this differed from the speed limit. The results show that a majority (90%) of the drivers did change the settings from the default settings. They preferred to be warned at 5-10 kilometres above the speed limit and 58% preferred audio and visual while 40% preferred visual only. As much as 93% of the test pilots thought that Speed Alert was very or quite good. Whether the possibility to change the settings themselves increased the acceptance of Speed Alert is hard to conclude from this study, but according to Adell (2007), adaptive HMI, making it possible to adapt the interface of the system to the specific needs and preferences, would increase acceptance.

Now, there are of course issues with participant selection and response rates in experiments that are as “free” as this, i.e. participants can more or less join and withdraw from the study as they please. Still, the number of very positive test drivers in a predominantly technology interested male population is remarkable. We also got quite a large number of calls and e-mails from test drivers that were very satisfied with the functionality.

What effect this will have on traffic safety is impossible to conclude from this study even though 93% of the participants stated that they became better or much better drivers with the system. One could argue that a system where the drivers set the limits themselves will probably have a limited effect on their mean driving speed, it could however have a large effect on their 85th percentile speed which would give a safety effect of the system. This is not tested in this FOT but can be considered plausible and would certainly be interesting to test in a more controlled experiment.

Another aim of the project was to increase the number of drivers using a Speed Alert/ISA-system. Even though the above analyses are based on 657 test pilots a total of 962 drivers did in fact test Speed Alert (the reason for not including all these drivers in the analyses was that some failed to answer the recruitment questionnaire) which has to be considered a great success. The test pilots trying the system also represent a wide age range and have a large yearly mileage (58% of them had driven 20 000 km or more during the previous year). Together with the high acceptance rate this bodes very well for further implementation.

With regards to using Speed Alert nearly all (94%) of the test pilots thought that installation went well and after installation they stated that they drove with Speed Alert activated for nearly half of the time (49%) or just above 1 000 km. Speed Alert was most frequently used on private- and business trips outside the test pilots’ home community and in environments unknown to them. As it is reasonable to believe that drivers know the speed limits by heart on

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1 The default settings were: Visual and auditory warning at the speed limit
roads that they travel often (for example to and from work) it is not surprising that Speed Alert was most frequently used in unknown environments where the speed limit information might be asked for by the drivers. Another reason to why Speed Alert was most frequently used in unknown environments could be that drivers are more interested in keeping the speed limits in environments where they lack knowledge about sharp bends, speed cameras etc.

With regards to the different settings on Speed Alert, the majority (73%) of the test pilots most frequently used the Navigation mode. Furthermore, the visual speed warning was seen as slightly more important and informative than the auditory speed warning even though the visual speed warning was also seen as being too small. As the size of the visual speed warning to a very large extent is limited by the size of the display of the mobile phone the size issue is hard to solve. At the same time, a clear majority of the test pilots (70%) stated that they never or very rarely had had any problems seeing the visual speed warning, which suggests that the size of the visual speed warning available in Speed Alert is sufficient even if a larger size would have been preferred.

A majority (90%) of the test pilots also chose to change the setting for how and when the warnings should be given. The most popular choice was visual plus auditory warnings at the speed limit or up to 10 km/h above it. Furthermore, test pilots who spent a lot of their driving distance above the speed limits chose to set the warnings further above the speed limits than did test pilots who spent little of their driving distance above the speed limit. This highlights a well known problem with different types of Speed Alert/ISA-system. At the same time as the ability to change the speed warning settings increases the acceptance of the systems it also decreases the effect the systems have on drivers’ speeding behaviour and therefore also the systems traffic safety potentials.

A majority of test pilots (69%) also stated that they had a great trust in the speed warnings given, even though 46% of the test pilots had sometimes received faulty information about the speed limits. This suggests that drivers are willing to accept a certain amount of faulty information before they lose trust in the system.

With regards to the effect of Speed Alert on drivers’ speeding behaviour the test pilots reported spending significantly less time exceeding the speed limits with 5 km/h or more when they had Speed Alert activated compared to before they downloaded the application. Unfortunately, the driving distance spent above the speed limits before the application was downloaded as well as when the application was not activated could not be measured using the current research design.

This means that the test drivers log data can not be compared for drives with and without Speed Alert. For drives with Speed Alert activated log data does however show that the test pilots still spent nearly half (43%) of their driving distance above the speed limits which is quite a lot – especially considering that this was with Speed Alert activated! Even so, a majority (93%) of the test pilots thought that Speed Alert made them much better or better drivers.

Finally, the test pilots thought that their petrol consumption and irritation decreased less than expected with Speed Alert and that the joy of driving had increased less than expected. One reason to why Speed Alert affected the test pilots less than they expected could be that they only drove with Speed Alert activated for approximately half of the time and that they still spent nearly half of their driving distance above the speed limits.

REFERENCES


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ABSTRACT
In Japan, many new technologies using Intelligent Transportation System (ITS) have been developed in order to reduce traffic accidents as well as to relieve traffic congestion. Adaptive Cruise Control system (ACC) is one of the ITS technology to avoid vehicle collision and has been introduced gradually in Japan. The impact to a driver’s behavior of installation of ACC to a single vehicle such as the technology for reducing collision could be evaluated by using a driving simulator. However, the impacts of ACC installation on traffic flow has not yet been evaluated because of difficulty of developing evaluation model such as including complexity of interaction among ACC and other vehicles’ behavior.

Thus, this study proposes to evaluate the impact of ACC installation on traffic safety by using a micro traffic simulation model. Since, conventional micro traffic simulation models can not represent the potential traffic accidents because the most of them control vehicles based upon the vehicle-following-theory which prevents occurrence of vehicles collisions. For this purpose, the micro simulation model was basically modified by adding a function of driving error and then detects conflicts or near miss situations emerged between vehicles on the simulation. Time Measured to Collision (TMTC) and Post Encroachment Time (PET) etc are tested as indicators to represent conflicts instead of actual traffic accidents occurrence. As the case study, this study demonstrates the impact of safety indicators by ACC installation on traffic flow with different installation rates and different flow conditions.

1 BACKGROUND
Many new technologies using ITS have been developed in order to reduce traffic accidents as well as relief traffic congestion. ACC which maintains headway distance to meet with driving speed seems to be one of the ITS to avoid vehicle collisions and has been penetrate gradually in Japan.

However, at the early stage of ACC promotion, traffic flows consist of vehicles with and without ACC that probably trigger increasing of cutting vehicles due to vehicles with ACC intents to keep wide headways. Therefore, it is necessary to evaluate the impact of ACC to
vehicles on traffic safety. Until now, the impact of introduction of ACC to a single vehicle on reduction of collision has been evaluated through a real vehicle or driving simulator. However, ACC’s impacts within traffic flow have not been examined because the evaluation model needs to include the variables of a normal vehicle’s acceleration and breaking rules and ACC vehicle’s automatic adaptation rule in a traffic flow.

Thus, this study proposed an approach to evaluate the impact of ACC installation on traffic safety by using a micro traffic simulation model that can represent a driving behavior of individual vehicle. Since there have not been any micro traffic simulation model which can depict traffic accidents because most of them control vehicles’ behavior based upon the vehicle-following-theory which does not cover collisions among vehicles. Solving this problem, this study basically modified the micro simulation model by adding a function of driving error and then detected the conflicts or near miss situation that means potential accident between vehicles occurred on the simulation.

TMTC and PET and so on were tested as indicators to represent conflicts instead of actual traffic accidents occurrence.

As the contents of this paper, in Chapter 2, specification of ACC is described for development inner rule of ACC vehicle in the simulation model. In Chapter 3, some conflict indicators by proposing the existing researches were introduced. Then, modifying micro simulation model by modeling ACC rule in the multi agents system and the result of case study were described in the chapter 4 and 5.

2 SPECIFICATION OF ACC

As an early type of the ACC, the vehicular gap warning system was commercialized by Nissan Diesel in 1989, which monitors headway of vehicles by using radar system and gives a proximity warning if headways are too small. In 1995, Mitsubishi Motors installed the world’s first ACC, the vehicular gap control system which can control engine output and a gear shift, to their vehicles and Toyota motors also started to install ACC in 2004. Currently ACC was installed on more than 100,000 vehicles in Japan.

Specifications of ACC are slightly different by automobile companies. However their fundamental functions are almost the same. ACC fundamental functions can be explained as follows and shown in Figure 1.

- Driving with constant speed if there is no front vehicle ahead.
- Maintain the headway distance set at appropriate level
  - If speed of a front vehicle is slower than setting speed, ACC decelerates speed
  - Follow a front vehicle to maintain the setting headway and adjust change of a front vehicle
  - If a front vehicle changes a lane, accelerate and continue constant running

Figure1: Fundamental specifications of ACC
ACC can be applied not only for the high-speed condition but also for low speed condition. According to the manual of ACC by each mobile company in Japan (HONDA 2003 etc), the high speed ACC is applied for driving speed from 40 km/h to 100 km/h on a freeway and also smooth flow condition without rapid acceleration. The low speed ACC is applied for driving for driving speed from 0 km/h to 40 km/h in traffic congestion but without stop and go. In addition recently the all speed ACC also is developed. The all speed ACC is applied for driving speed from 0 km/h to 100 km/h. This study targeted the high speed ACC. The target headway for any ACC can be set at three ranges, long, middle or short which can be defined by represent running speed. Table 1 shows relation of target headway distance and running speed of HONDA ACCORD HiDs system. In Chapter 4, these ACC’s adapting rules is used as ACC vehicle acceleration behavior in the evaluation model.

<table>
<thead>
<tr>
<th>Running speed Target headway distance</th>
<th>80km/h</th>
<th>100km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td>56m</td>
<td>69m</td>
</tr>
<tr>
<td>Middle</td>
<td>43m</td>
<td>53m</td>
</tr>
<tr>
<td>Short</td>
<td>33m</td>
<td>46m</td>
</tr>
</tbody>
</table>

3 CONFLICT INDICATORS
Traffic safety measures such as improvement of intersections usually are evaluated by comparing a number of traffic accidents. However traffic accident is probabilistic incident and it takes long time for collecting traffic accident data. On the other hand, according to Heinrich’s law (Heinrich, 1931), the constant ratio between fatal accident, light accident and near-accident (conflict incident) is 1:29:300. Thus conflict incidents can be collected in a short term through driver’s reports etc (Okamura, 2008). Existing studies (Motoda, 1992) also show interrelation between conflict incident and revealed traffic accident. Therefore, in this study, conflict incident is used as indicator instead of revealed traffic accident for evaluating the safety impact of ACC in a traffic flow. In the existing researches, some conflict indicators were suggested. For this study, TMTC, PET, difference of space distance and stopping distance are used as safety indicators and they are explained as follows. In the evaluation model, these safety indicators are observed depending on ACC installation rate in a traffic flow.

3.1 Time Measured to Collision
The TMTC suggested by Hayward, J.C. (1972) refers to the time to collision with a leading vehicle when both vehicles keep running with same direction in constant speed. A calculation method of the TMTC is shown in Figure 2. T_1 is the time of following vehicle braking. T_2 refers the time of collision between following vehicle and leading vehicle. The TMTC is a difference of T_1 and T_2. If the TMTC is less than driver’s perception time and brake reaction time, the collision will happen. The TMTC is usually used for various safety tests because of it’s simple definition. However, if speed of a leading vehicle is faster than a following vehicle, the TMTC cannot be calculated. In addition, a risk of accident is likely underestimated in the case of shorter headway distance or high speed.

3.2 Post Encroachment Time
The PET suggested by Allen, B.L. (1978) shows the time from the end of encroachment to the time that the following vehicle actually arrives at the potential point of collision. A calculation method of PET is shown in Figure 3. T_3 shows the time of leading vehicle conducts cutting. T_4 shows the time of following vehicle reaching the point on which the leading vehicle started...
to cut in. PET is defined as the difference of $T_3$ and $T_4$. The PET is an obvious measurement of how nearly a collision has been avoided.

Figure 2: Time measured to collision
Figure 3: Post encroachment time

3.3 Difference of Space Distance and Stopping Distance
Traffic Engineering handbook issued by Japan Society of Traffic Engineers and some literatures (JSTE, 2005 etc) define difference of space distance and stopping distance (S-Stop) as an indicator of safety. Space distance can be calculated by sum of headway distance and breaking distance of a leading vehicle as shown in Figure 4. Stopping distance can be calculated by sum of break reaction distance and break distance of a following vehicle. The indicator shows comparative freeze position of a following vehicle and a leading vehicle when a leading vehicle brakes suddenly and then a following vehicle also breaks to avoid collision. Negative indicator means happening of collision due to a flowing vehicle cannot avoid colliding with a leading vehicle in sudden brake.

Figure 4: Difference of space distance and stopping distance
4 EVALUATION MODEL FOR ACC INSTALLATION

4.1 Following Behavior of Non-ACC Vehicle

The traditional car following model such as the GM model (Denos, et.al., 1959) cannot be applied to simulate following behavior on a micro simulation model because acceleration becomes zero when relative speed between the leading vehicle and following vehicle becomes zero as in Equation 1. In addition, driver error should be added for creating dangerous situation because of car following model cannot happen accident.

\[
\dot{V}_{t+T} = \alpha \frac{[\nu(t)]^m}{[D(t)]^l} \{V_{t(0)} - V_t\}
\]

where

\[
\begin{align*}
V &= \text{speed of target vehicle} \\
V_l &= \text{speed of leading vehicle} \\
\alpha &= \text{sensitivity parameter} \\
D &= \text{headway distance} \\
m, l &= \text{Parameter}
\end{align*}
\]

Xing’s model (Xing, 2008) was employed for this study. Xing’s model is car following model that included perception-response process in Gipps model (Gipps, 1981). The perception-response process consists of three factors which are Visual expansion rate, Change of distance and Instantaneous time gap. The visual expansion rate is computed as in Equation 2. Change of distance is simply the difference between current headway distance and the headway distance at the previous scanning interval. The instantaneous time gap is derived by dividing current headway distance by subject vehicle’s instantaneous speed.

\[
\theta = \frac{W \cdot |\Delta V|}{D^2}
\]

where

\[
\begin{align*}
\theta &= \text{the visual expansion rate;} \\
W &= \text{vehicle width;} \\
\Delta V &= \text{relative speed;} \\
D &= \text{headway distance;}
\end{align*}
\]

At each scanning interval, the following questions are checked.

1. True or False: visual expansion rate \( \theta \) exceeds the threshold \( C_\theta \).
2. True or False: change of distance exceeds the threshold \( C_D \).
3. True or False: gap time outside of \([1-E_g \cdot t_{g'}, (1+E_g \cdot t_{g'})]\).

where

\[
E_g = \text{time gap error;} \\
t_{g'} = \text{driver’s desired following gap time;}
\]

If all three answers are false, then the vehicle does not accelerate or decelerate. When neither of these checking results is true, Gipps model is used. Gipps model is shown in Equation 3-5.

\[
V_{t(t+T)} = \min \left[ V_{a(t+T)}, V_{b(t+T)} \right]
\]
\[ V_n(t+t_g) = V_n(t) + 2.5a_n t_g \left( 1 - \frac{V_n(t)}{V_n^{max}} \right) \sqrt{0.025 + \frac{V_n(t)}{V_n^{max}}} \]  

\[ V_n^b(t+t_g) = -t_g b_n + \sqrt{t_g^2 b_n^2 + b_n \left\{ 2(x_n(t-1) - x_n(t) - s_0) - t_g V_n(t) + V_{n-1}^2/b_{n-1} \right\} } \]  

where

- \( t_g \) = reaction time;
- \( a_n \) = maximum comfortable acceleration rate for vehicle \( n \);
- \( b_n \) = maximum comfortable braking rate for vehicle \( n \);
- \( x_n, x_{n-1} \) = position of vehicle \( n \) and \( n-1 \), respectively;
- \( b_{n-1} \) = \( n \)th driver’s estimation for \( n-1 \)th vehicle maximum comfortable braking rate;
- \( V_n^{max} \) = desired free flow speed of vehicle \( n \);
- \( S_0 \) = headway distance at standstill;

4.2 Following Behavior of ACC Vehicle

Actual algorithm on ACC was not opened to public so that we developed an algorithm for ACC based on the specification which was explained in Chapter 2. In this study, we evaluate high speed ACC. When the velocity of ACC vehicle is faster than 45km/h, the vehicle will behave as ACC vehicle and when the velocity is under than 45km/h, it will obey Xing’s model. Maximum acceleration rate and deceleration rate of ACC vehicle set 2.0 m/s² and -2.5 m/s² that are fixed by ISO. The algorithm flow chart for ACC was shown in Figure 5.

![Algorithm Flow Chart for ACC](image-url)
To evaluate an impact on traffic flow after widespread use of ACC, Paramics as micro traffic simulation (Quadstone, http://www.paramics-online.com/) was used basically and following behavior of a Vehicle with/without ACC which was developed by API was put. Vehicle’s lane changing behavior was depended on initial setting of Paramics micro simulator.

5 CASE STUDIES

5.1 Setting Parameter
Impact of ACC was calculated by modified traffic simulation as shown in Figure 6. The circle inside of Figure 6 represent happened conflict incident. The simulation patterns are 10 patterns as shown in Table 2. Each pattern was calculated 10 times. Parameters in models were set randomly based by existing studies as follows. Studies

\[ C_0 \text{ (The threshold)}: 0.003-0.004; \]
\[ C_D \text{ (The threshold)}: 0.1-0.2; \]
\[ E_g \text{ (Time gap error)}: 0.2-0.8 \text{ sec}; \]
\[ t_g \text{ (Reaction time)}: 0.3-1.0 \text{ sec}; \]
\[ a \text{ (Maximum comfortable acceleration rate)}: N (1.7, 0.3^2) \text{ m/s}; \]
\[ b \text{ (Maximum comfortable breaking rate)}: 2.0 \text{ m/s}; \]
\[ V_{\text{max}} \text{ (Desired free flow speed)}: N (27.3, 4.4^2) \text{ m/s}; \]
\[ \hat{b} \text{ (Estimation maximum comfortable braking rate)}: 2.5 \text{ m/s}; \]
\[ S_0 \text{ (Headway distance at standstill)}: N (6.5, 0.3^2) \text{ m}; \]

Setting speed of ACC vehicle: N (27.3, 4.4^2) m/s, (maximum speed is 27.8 m/s); Reaction time of ACC: 0.2 sec;

![Figure 6: Modified traffic simulation model](image)

<table>
<thead>
<tr>
<th>ACC rate</th>
<th>0%</th>
<th>0%</th>
<th>25%</th>
<th>25%</th>
<th>50%</th>
<th>50%</th>
<th>75%</th>
<th>75%</th>
<th>100%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. lane</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Simulation time (min)</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Time step (sec)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>
5.2 Results of Simulation

The results of simulation are shown in Figure 7-18. The 6 indicators of mean headway distance, mean of minimum headway distance, mean of maximum deceleration, mean TMTC, mean PET, and mean S-Stop are shown as safety indicators or conflict indicators. The box plots show minimum value, 15 percentile, 85 percentile and median value. Minimum values are not shown.

Mean of headway distance and minimum headway distance showed that headway distance of ACC vehicle is wider than non ACC vehicle as indicated in Figure 7 and 8. Mean of maximum deceleration increased as installation rate of ACC increased in Figure 9. 15 percentile of mean TMTC increased as installation rate of ACC increased as shown in Figure 10. Mean PET and S-Stop showed the almost same value by installation rate as shown in Figure 11 and 12.

The results of simulation in the case of 2 lanes are shown in Figure 13-18. Mean headway distance increased as installation rate of ACC increased as shown by Figure 13. Nevertheless mean of minimum headway distance showed the different tendency of mean headway distance. Mean of minimum headway distance showed almost the same value by all installation rates as shown by Figure 14. Minimum of maximum deceleration, mean PET and mean S-Stop improved as installation rate of ACC increased as shown by Figure 15, 17 and 18. On the other hand mean TMTC of 25%, 50% and 75% rate were smaller than 0% and 100% rate as shown by Figure 16.
Figure 1: Mean PET (1 lane)

Figure 2: Mean S-Stop (1 lane)

Figure 3: Mean headway distance (2 lanes)

Figure 4: Minimum headway distance (2 lanes)

Figure 5: Maximum deceleration (2 lanes)

Figure 6: Mean TMTC (2 lanes)

Figure 7: Mean PET (2 lanes)

Figure 8: Mean S-Stop (2 lanes)
5.3 Consideration
As the result in the case of 1 lane simulation, all indicators showed safety except the mean of maximum deceleration depending on increasing of ACC installation rate. However the mean of maximum deceleration is no problem because its range was included in 0.0-5.0 m/s² that is fixed by standard of ACC as safety deceleration. The result of headway distance showed that ACC vehicle could maintain wide headway distance. PET and S-Stop of ACC vehicle also showed same value with non ACC vehicle. In this simulation case, traffic demand was not high. Thus, 0% case and mixing rate case could not simulate dangerous situation. We should simulate other demand case as the future issue.

As the result in the case of 2 lanes, almost indicator showed safety as installation rate of ACC increased. However, Mean TMTC of mixing flow with ACC vehicle and non ACC vehicle showed small value than 0% rate and 100% rate. We think that the reason was increasing the case of cutting vehicle to in front of ACC vehicle by non ACC vehicle.

6 CONCLUSIONS
This study proposed an approach to evaluate the impact of ACC on traffic safety using a micro traffic simulation model. The evaluation model was consisted by Paramics as the micro traffic simulation and behavior of with/without ACC was developed by API of Paramics. TMTC and PET etc were tested as indicators to represent conflicts instead of actual traffic accidents occurrence. As a result of simulation, ACC is useful to improve safety. However, it was shown that the mixing flow of ACC and non ACC on the 2 lanes has possibility to decrease safety by increasing the cutting vehicle.

This study could show the approach for evaluate the impact of ACC on traffic safety using the micro simulation model. However some indicators showed different tendency. As the future issue, we will show that each indicator connect with which type of potential accident. In addition, we should simulate other traffic flow case by traffic demand will be change and will show relationship with safety and efficiency of traffic flow.

REFERENCES
Hayward, J.C. (1972). Near-Miss determination through use of a scale of danger. HRR 284, pp.24-34.
Contents session 11  Road user education, driver licenses, special user groups: young, old vulnerable

Ambient Intelligence in Driving Simulation for Training Young Drivers  
*Evangelos Bekiaris, Hellenic Institute of Transport, Greece*

Improving Driver Education with Multimedia Applications  
*Tibor Petzoldt, Chemnitz University of Technology, Germany*

The New Road Safety Programme for Comprehensive School of Lithuania: Theoretic and Didactic Aspects  
*Rytis Vilkonis, Faculty of Education, Siauliai University, Lithuania*

Experiences of Helmet Wearing Promotion and Enforcement in Cambodia  
*Chandy MEAS, Handicap International Belgium, Cambodia*

How to Promote Traffic Safety Among Youth?: A Multiple-approach Plan from Luchemos por la Vida  
*Maria Cristina Isoba, Luchemos por la Vida, asociación civil, Argentina*
AMBIENT INTELLIGENCE IN DRIVING SIMULATION FOR TRAINING YOUNG DRIVERS

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ABSTRACT

Until today, the driving behaviour of the surrounding traffic used in the simulation technology was according to the traffic laws, i.e. the simulator driving environment is always smooth and the driver focuses only on his/her own driving and the specific tasks that are requested by the respective program/exercise that he/she follows. Therefore, when training a driver trainee with the simulator, there is a need to present a realistic traffic environment, i.e. among the traffic participants, also include those that do not behave as expected, either because they brake the law or because they are not able to estimate a given situation and react properly.

Within the TRAINFALL project (co-funded by the EC, 6th FP), a number of innovative simulator modules were developed for motorcycle riding, passenger car (both for novices and emergency drivers) and truck driving. The new tools include also VR-based immersive simulation tools, as well as a common architecture and a modular simulator design process for multi-user, group training. Among the developed tools is the Ambient Intelligence (AI) module constituting an important novelty in terms of its concept and functionality. It extracts the profile of actual drivers in simulator scenarios and transforms it to surrounding vehicle behaviour profile (thus creating natural traffic participants in simulator scenarios).

The inclusion in the simulation of other traffic participants, that interact naturally (not always legally though) with the trainee, allows to “fully immerse” the driving simulator into a realistic traffic environment. Thus, it is different from just introducing artificially illegal or varying traffic behaviour to surrounding vehicles, as in this case, the introduced behaviour is a natural and random one. By mixing “true” traffic simulation and multi-user driving simulator, a new generation of computer-based training tools may emerge. Thus, the aim here is to have a more natural traffic behaviour in the driving simulation-based training process, so that the trainees can be trained on the real – and sometimes unexpected – traffic behaviour of other road users.

1 INTRODUCTION

There is pan-European consensus on the fact that driver training needs to expand away from its current focus on controlling the vehicle in traffic; so as to cover “higher level” strategical factors, such as journey-based decisions and the ability to realise and cope with the way that personal traits affect driving behaviour and risk acceptance (Ulleberg, P., 2003).

TRAIN-ALL developed an integrated, single platform, modular, computer-based system for land-based drivers (of passenger vehicles, motorcycles, trucks and emergency vehicles). The
developed system is cost-effective (creates viable business), adequate both for training, assessment and monitoring of the driver and include all modes of operation (pre-trip, on-trip, emergency handling).

Since in real driving conditions are not always smooth, and there are drivers who do mistakes or disobey traffic rules, the drivers must be trained, in order to be ready to compensate such unexpected situations. Moreover, not all drivers drive in the same way, i.e. the driving style differs heavily among drivers. The driving behaviour is characterised by several factors, such as: time to collision (TTC) or time headway (TH), time to line crossing (TLC), reaction time (RT), etc. Taking the RT as example, although it can be considered as one parameter, in reality it consists of various factors. According to the literature (e.g. Green, 2001), a driver’s reaction time is composed by the mental processing time and the action time. The reaction time differs per driver, with big variations, ranging from 0.6 seconds for a professional driver to 0.8-1 sec. for a “mean” driver, and up to 1.5-2 sec. for some elderly drivers. Drowsy drivers might have even bigger reaction times.

In addition to the above, other important factors that contribute to differences in the driving behaviour are the age, experience and even cultural differences. For the latter, it is useful to know the overall behaviour of tourists, as drivers, when driving in foreign countries. Examples of ‘real’ (abnormal) behaviour of other traffic participants, that is supported and can be visualised with the AI module, is:

- not following the proper distance to the vehicle in front;
- not driving in the centre of the lane;
- not having a fast reaction time.

2 AMBIENT INTELLIGENCE MODULE SPECIFICATION

As there are practical infinite simulator scenarios where driver behaviour data could be monitored and a very wide number of parameters to describe them that could be stored, a selection of both scenarios and parameters was made, aiming to satisfy all the relevant Use Cases and to focus on the most representative scenarios used for driver training in a simulator environment. The use cases applying to the AI module follow below:

1. Personal driving style storage
2. Driving with “natural” traffic around
3. Training by use of stored profile

More details per use case (on the scenarios, critical success parameters, etc.) can be found in TRAIN-ALL Deliverable 1.2 (Poschadel S. et al., 2008).

DRIVABILITY is a dynamic model which is defined as a combination of permanent and temporarily factors that affect driver's performance. More specifically, it is an indicator of driving performance, which matches individual resources, experience, situational influences, namely environmental factors and workload, and human errors with accident rates (Bekiaris et al, 2003). In order to create a first personalized profile for the driver, three parameters were selected which are based on the most important driving ability parameters of the DRIVABILITY model, each one corresponding to a different type of driver behaviour. These parameters are used in previous research projects (ADVISORS, IN-ARTE, etc.) and in the literature (Martens & van Winsum, 1999, Van Winsum και Godthelp, 1996, Panou 2008, etc.)
for defining driver behaviour. Thus, these are the parameters that are studied, whenever the researchers want to study any changes in the driving behaviour, in case of e.g. introduction of a new ADAS, etc. or when building the personal driving profile of a driver (for the provision of personalized warning/info). These parameters are:

- Longitudinal behaviour: TTC and/or TH
- Lateral behaviour: TLC (left and/or right)
- Emergency behaviour: Reaction Time

The above parameters are needed for the deployment of the first use case listed above.

The real driver profiles that have been created, are attributed to road traffic participants of a new scenario. In this scenario, a driver is driving for at least 15 minutes in different traffic environments (urban, rural, highway) and has an interaction with at least 5 different surrounding vehicles, having generic (control-case) or personalized behaviour. The other traffic participants should alternatively:

- Be in front of the reference driver and at some point perform emergency braking (i.e. because of an animal crossing the road).
- Follow the reference driver at their typical TTC/TH.
- Overtake the reference driver, using their normal TLC.

In addition, the reference driver should be instructed to overtake at least three different of the surrounding vehicles and perform a sudden braking, in order to experience the actual behaviour of the naturally behaving surrounding vehicle.

The mean values of the driving behaviour parameters are then compared to normative values from the literature. Based on them, as well as their relaxation, according to TRAINER (Deliverable 5.1, Pirenne D. et al., 2002) project results, a decision about the need of retraining is given by the system.

2.1 Methodology for the module development
The step-by-step methodology followed for the development of the Ambient Intelligence module in TRAIN-ALL, is summarized in the following list:

- Definition of the key parameters characterizing driver behaviour.
- Selection of key tasks to monitor driver behaviour.
- Development of driving simulator scenes for those tasks.
- Development of log files for simulator to measure these parameters in each task.
- Storage of key parameters together with driver profile data (age, nationality, gender, driving experience) and in reference to the specific driving task.
- Use of the above specific data for personalization of training by the trainer (off-line).
- Storage of the above profile data in a driver behaviour database per driving task.
- Use of data on the above database for characterizing the key driving behaviour of surrounding vehicles (i.e. following distance, position in the lane) in future runs of other drivers in the same driving simulator tasks.

3 SCENARIOS AND TECHNICAL CHARACTERISTICS
Scenarios have been realized by two simulator developers (WIVW and FOERST) for the measurement of the driving behavior parameters and for the use cases listed in section 2.
Different scenarios are implemented for different road types: urban, rural and highway. The scenarios developed by FOERST are displayed below. These have been implemented in the driving simulator of CERTH/HIT.

The first three scenarios belong to the use case ‘Personal driving style storage’.

In the first one, while the trainee is driving, there are different events happening and the driver is supposed to brake. At each event the reaction time is measured. In different road types (urban, rural, motorway), various sudden events happen, such as a child who is crossing the street following a ball, a parking car opening the driver’s door, an animal jumping on the street from the left or the right, etc.

![Figure 1: Reaction time measurement scenario](image1)

In the next scenario, the trainee is freely driving in an urban area, on a rural road or a motorway and the TLC_left and TLC_right are recorded. There are no special events happening. The road types used are urban, rural and motorway.

![Figure 2: Time to line crossing measurement scenario](image2)
The last scenario for the first use case requires that the trainee is freely driving in an urban area, on a rural road or a motorway and the TTC and TH are recorded. There are no special events happening.

Figure 3: Time to collision measurement scenario

For the rest two use cases, the developed software does not consists of specific visual scenarios with graphics, as is the case with the first use case.

The application creates a driver behaviour model, which is based upon a set of objective parameters (TTC, Headway, TLC left, TLC right and reaction time). It creates an anonymous profile of a driver, which is later used as a traffic participant with its average value for any of the above-mentioned parameters. Also, the traffic participant model is created and the user can fill values for each of the model's parameters. These parameters are age, gender, nationality and driving experience of the driver.

Figure 4: Create an anonymous behavioral model
Furthermore, the trainer can view the values for any traffic participant.

4 PRELIMINARY TESTS RESULTS

The Ambient Intelligence module is currently being tested with real users. Through the tests, all the 3 UCs that were described in section 2 above will be evaluated. The scenarios are addressed to both driver trainees and trainers. Below, the results arising from the verification pilots, are given. Five drivers participated in those tests. The aim of the verification pilots is to assess the functionality and the efficiency of the variety of simulated driving behaviours. The main hypothesis is that the immersion of real life scenarios will facilitate training.

<table>
<thead>
<tr>
<th>Rating parameters</th>
<th>UC 1</th>
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<th>UC 3</th>
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<td><strong>Generic performance</strong></td>
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<td>Application loading time</td>
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<td>Validity (%)</td>
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<td>Usability</td>
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<td>Usefulness</td>
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<td>Impact on the trainee’s driving ability level (assessed by instructor)</td>
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<td>NA</td>
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<td>Faster reduction of individual errors</td>
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<td>M</td>
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<td>Acceptance by trainers/ trainees</td>
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<td><strong>Ambient Intelligence Module</strong></td>
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<td>Modelling time</td>
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<td>Modelling fidelity</td>
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<td>Perceived naturalistic behaviour (by other drivers)</td>
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<td>Cost efficiency</td>
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*S*: Successful, *NS*: Non successful

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| | S | S | S |
| | H | H | H |
| | M to H | M to H | M to H |
| | M to H | M to H | M to H |

**Table 1**: Performance of the AI module during the verification results

The above table was filled in taking into account both objective (logfiles) and subjective measurements (pre and post questionnaires) and as a summary of the verification process and reflects the participants’ greater picture of the module’s performance.

Sumarising, users were satisfied by the overall technical performance of the AI module and mentioned that it would be a highly useful and usable module for driving trainees. However, they could not differentiate the “embedding” of their own personal profile within the simulated drives, thus they could isolate and identify mistakes in other drivers’ behaviour but they were not able to correlate them to their own errors. The trainer could provide an account of the relation between trainees’ mistakes or misses to the simulated account of their profile.

As shown above the specific success criteria were met. The effort towards an ambient intelligence standard in driving education could be perceived as a more pragmatic and sharp behavioural attitude towards education, which is potentially applicable to specific country needs.
In addition, demonstration pilots are underway, with 75 novice drivers. During the demonstration pilots, the modeling time, the modeling fidelity, the perceived naturalistic behaviour (by other drivers) and the cost efficiency are the module-specific critical success parameters that will be measured with the pilots. Among the rest success parameters (more generic ones), are the validity (%), usability, usefulness, acceptance by trainers/trainees, etc. In addition to the common questionnaires that will be used for the pilots, a dedicated short questionnaire has been designed, aimed for the pilot sites that will evaluate the AI module.

5 CONCLUSIONS

The Ambient intelligence module tool, which monitors and extracts the profile of actual drivers in simulator scenarios and transforms it to surrounding vehicle behaviour profile (thus creating natural traffic participants in simulator scenarios), is by itself a big innovation in terms of the concept and functionality.

Preliminary users’ comments that tested the AI module suggest that it supports the notion of human interaction with the surrounding traffic and the environment, which is essential for user empowerment within the simulation evaluation framework.

The personalized profiles that are built with the AI module, define the personal driving style of each driver. This is a concept that is applied for the first time, and it is of high value, as the stored driving profiles of the drivers can be used for many applications in the future, such as:

- the detection of driver’s problematic areas that can be used for suggesting appropriate training measures;
- the development of driver-specific personalized ADAS for a more efficient driver warning;
- statistics and analysis of main factors that contribute to traffic accidents;
- when most amounts of data are collected from driving schools in Europe or Worldwide, for demographic studies on the impact of different personal parameters (age, training level, socioeconomic background, cultural, etc.) to driving style, as well as the effects of various training methods and scenarios.

Extended tests are underway for excessive validation of the module in three sites Europewide, with 75 drivers (novice car and truck drivers). Tests results are expected to provide feedback on the added value that trainees and trainers see on scenario reliability and naturalness by the use of personalised and natural traffic participants in the simulator environment, as well as on personalised training, based upon the monitoring of key driver behaviour objective parameters. Also, the relevant thresholds proposed are going to be assessed in each driving simulator and modifications to them are expected. In case this module proves to have significant added value for trainees and/or trainers, the existing architecture and s/w platform can be easily expanded to other traffic scenarios (i.e. overtaking or junction negotiation behaviour), as well as simulator types (i.e. truck, bus or motorcycle).

6 REFERENCES


Ulleberg, P. (2003), Amount of driver training with a lay instructor among adolescents aged 16 and 17 (Norwegian, with summary in English) TØI Report 675. Oslo: Institute of Transport Economics.

ABSTRACT

Novice drivers are in danger. This insight is neither new nor surprising. However, whatever measures have been taken to solve this problem, crash rates among inexperienced drivers are still alarmingly high. One major contributing factor is the novices’ age, with all the problems that go along with being young and trying to find one’s place in the world. Yet, there is also the lack of skills that has a tremendous influence on accident involvement of younger drivers. Conventional forms of driver training have largely failed to build up some skills that go beyond a rather descriptive knowledge of how to drive. Computer based trainings are supposed to provide new ways of dealing with this issue. This paper reviews some of the applications available and reports on an effort to develop such a computer based training tool within a German context.

1 INTRODUCTION

Crash statistics show an extremely high risk for novice drivers to be involved in traffic accidents, much higher than for experienced drivers. According to the OECD, “Traffic crashes are the single greatest killer of persons aged 15-24 in OECD countries, accounting for 35% of all deaths, or approximately 25,000 people annually in recent years.” (OECD, 2006, p. 27). 27% of all traffic fatalities occur in the group of young drivers, although they represent only 10% of the population. In Germany, every fifth road fatality or injury occurs in the age group of 18-24, although this group accounts for only one twelfth of the overall population (Statistisches Bundesamt, 2008). Occupants and motorcyclists represent roughly 91% of road fatalities in this age group, which is much more than in any other cohort. It is clear that young drivers are at increased risk on the road and at the same time are also a major hazard for other road users.

A model proposed by Gregersen and Bjurulf (1996) tries to explain young driver’s accident involvement. They identify social and individual circumstances as well as the learning process as the causal factors that influence accident involvement in various ways. Social influence and individual preconditions mainly refer to age related characteristics of novice drivers. Subjective norms differ fundamentally in the young driver’s age group. These are supposed to heavily influence his/her decisions about why and how to drive, usually in a way that makes the young driver more accident prone than an older counterpart. At the same time, the lack of driving experience and therefore the not-yet-fully developed skills necessary for safe driving add to this problem. There is a vast amount of experimental research pointing to the fact that novice drivers have deficits especially in driving relevant cognitive skills. Whelan and colleagues (2004) found differences in hazard perception and situation awareness between novice and experienced drivers, which is in line with similar research on the effects of experience on hazard perception (eg. Crick & McKenna, 1992; Mills, Hall, McDonald, & Rolls, 1998). Sagberg and Bjørn Skau (2006) report on findings from a hazard perception test in which, although the average reaction times tended to decrease, there was no statistical...
significant effect of experience. They conclude that hazard perception might be only a minor factor in explaining the initial risk decrease among novice drivers. However, the majority of findings clearly point to hazard perception as a critical deficit in novice drivers, a fact that finds reflection in the introduction of hazard perception tests in the licensing process in several countries. Another issue is calibration, which is the balancing of task demands and capabilities (Kuiken & Twisk, 2001). Novice drivers have problems to correctly assess task demands, which is reflected in their failure to perceive and evaluate specific driving situations as being risky (Finn & Bragg, 1986). At the same time, there seems to be a huge disparity between novice drivers’ assessment of their driving skills, and their actual capabilities, which leads to fatal errors when it comes to adjusting the task demands (speed, overtaking etc.) to the resources available. Although an overestimation of abilities is rather common for all age groups of drivers (e.g. Svenson, 1981; Groeger & Grande, 1996), novice drivers seem to be especially prone to this kind of misjudgement. Matthews and Moran (1986) report that young male drivers tend to rate their skills similar to those of older drivers, a result that was later confirmed for young drivers in general (Groeger & Brown, 1989). Given the difference in driving experience between these two groups, it is clear that the younger drivers are at much higher risk of mismatching the driving task demands to their skills.

Traditional formal driver education seems not to be able to deal with these issues. Indeed, as Mayhew and Simpson (1996) demonstrate in their review, the claim that institutionalized driver education provides a safety benefit over private instruction still lacks scientific proof. However, Mayhew (2007) argues that, despite this fact, it is important to not give up driver education. It is rather necessary to use the opportunities that are available to improve driver education so that it achieves its safety objectives. One of those opportunities is computer based training (CBT). The rise of multimedia applications has provided new ways of delivering content to the learner. One of the most important aspects is the possibility to include animated content, be it actual video footage or other kinds of moving pictures. Learner drivers can experience potentially critical situations without actually endangering themselves or others. As there is much more realism to such animated depictions compared to static images in a textbook, this can be considered a true benefit of CBTs. The adaptability of such training to a trainee’s needs, both in the training in general (e.g. in setting different levels of difficulty depending on pre-test results) as well as in a specific item (e.g. repeating questions when answered wrong, giving feedback depending on answer), constitutes another major advantage over learning from a textbook or following a lecture. Yet, as Niegemann and colleagues (2004) note, many of those multimedia applications do not meet expectations, as the unique characteristics of new media alone are not sufficient to create an impact. There always needs to be a proper instructional strategy in place to fully exploit the opportunities the media of choice provides. Also, the use of CBTs puts a higher demand both on the learner and the teacher. Important keywords in this regard are media literacy or self learning competence (Schnotz, Seufert, & Bannert, 2000). The sole incorporation of new media features in a training program is therefore obviously not automatically effective. A theoretically sound design of the application, including appropriate instructional strategies, is absolutely essential.

2 MULTIMEDIA APPLICATIONS

As broad as the term „multimedia” is, as diverse are applications that make use of the opportunities new media are providing to improve driver education. Within a German context, one can broadly categorize into “teaching applications”, “home training applications” and driving simulators (Weiss, Bannert, Petzoldt, & Krems, 2009). Teaching applications are used in driving schools to impart the theoretical knowledge that is required to pass the exam. Despite being very comprehensive and flexible, those tools are no solution for the problem of lacking cognitive skills, since this is not the primary focus of the theoretical driving school lessons. The home training applications available in Germany also primarily concentrate on
knowledge rather than skills. There is as vast amount of software packages that basically only provide multi-choice-questions similar or identical to those in the theoretical exam. Driving simulators are available only in very few driving schools in Germany. So, from practical point of view, they cannot provide a quick solution either. In addition, although they are believed to bear some educational potential (van Emmerik, 2004), research on simulators in driver training has so far mainly focused on technical aspects (e.g. Reed & Green, 1999; de Winter et al., 2007), neglecting the investigation of cognitive training opportunities in this virtual environment.

Thus, although there are some multimedia applications available in Germany, none of them appears to be suitable to tackle the issue of insufficient cognitive skills. Therefore, we reviewed a number of applications that are available elsewhere, namely Driver-ZED, DriveSmart, CDDrives and RAPT3. Those tools explicitly address cognitive skills like hazard perception or risk assessment. At the same time, they only require a minimum of organizational and technical effort to be employed. So, apart from the necessity of a standard PC, there are no further constraints for a potential user, a fact that makes them rather attractive as role models for a CBT tool that is supposed to enhance the process of driver education the biggest share of the population. We are well aware of other products that share features of the reviewed ones. However, we tried to focus on applications that are closely related to our theoretical approach. Also, a proper scientific documentation of the respective application in terms of theoretical underpinnings as well as evaluation if available were believed to be necessary to get a deeper understanding of the processes at work.

2.1 Driver-ZED

Driver-ZED is a training product that has been released by the US American AAA Foundation for Traffic Safety (Blank & McCord, 1998; Lonero, Clinton, & Black, 1998; Willis, 1998). Within the program, sequences of real world driving videos are presented that contain various types of traffic risks. Sequences display either a town, country or city scenario. The mode of interaction varies between answering questions concerning the traffic environment after the sequence (“scan”), identifying risky elements in the scenario before the end of the scenario (“spot”), indicating what actions to take to avoid a risky situation (“act”) after the sequence, and indicating when to take action and what action to take (“drive”) while the scenario is running. In their evaluation, Fisher and colleagues (2002) report that the training increases young drivers’ awareness of risks one to two weeks after training is completed. However, long-term effects are still unclear.

2.2 DriveSmart

DriveSmart (Regan, Triggs, & Wallace, 1999) is an Australian product that has been developed by the “Monash University Accident Research Centre“ (MUARC), for the “Transport Accident Commission“ (TAC). The CD-ROM can be ordered by learner drivers in the Australian state of Victoria free of charge since 2000. Building onto findings about accident involvement of novice drivers (Triggs, 1994), the focus of this application is on risk perception, attention control, timesharing and calibration (Triggs & Regan, 1998). The program makes use of small digitized video clips that require different forms of intervention by the user. There are tasks like marking key risks in a stopped video (“key risks”), recalling events with the screen blank (“recall”) or predicting what might happen next (“prediction”). Further quests include selecting an appropriate reaction to a situation in a multi-choice-question (“selecting options”), positioning the surrounding vehicles from a birds view (“drag & drop”), indicating the development of a risky situation (“pausing video”) and commenting on the developments of the scene in general (“record your commentary”). There also is an additional simulation-based module that deals with the assessment and regulation of distances (“headway task”) concurrent to a cognitive secondary task (“number task“). An experimental
evaluation of the program suggests that it is effective in terms of attention control as well as hazard perception (Regan, Triggs, & Godley, 2000). Effects were still present four weeks after the training. Also, it is reported that the training did not lead to differences in the novice drivers’ self-assessment of their capabilities which is a crucial aspect considering the aforementioned calibration problems of young drivers.

2.3 CDDrives

CDDrives has been developed by the University of Waikato in New Zealand. It is element of the “practice programme”, a New Zealand road safety initiative. Learner drivers can obtain a so-called “practice package” that contains CDDrives for free. The application is another video-based approach (Cockerton & Isler, 2003) to teach cognitive driving skills on a PC that is explicitly based on Driver ZED and DriveSmart (Isler & Cockerton, 2003). It consists of five different modules that differ in the tasks to be completed. The “eye scanning” module requires the monitoring of the traffic environment as well as the inside of the vehicle to correctly answer multiple-choice-questions. In the “hazard detection” module, hazards have to be marked either in a final picture of the scene or directly in the running sequence. “Risk management” requires the stopping of the sequence once a potential hazard is identified, to then answer a multiple-choice-question on the correct response to the hazard. Within the “road commentary” module, the events around the vehicle are to be commented on. The “final challenge module” incorporates aspects of all previous modules (except “road commentary”). An evaluation of the applications’ effectiveness is not available.

2.4 RAPT3

The RAPT („Risk Awareness and Perception Training“) is an application developed by University of Amherst, Massachusetts. The tool is used solely for scientific purposes and can be downloaded from the institute’s website. In contrast to Driver ZED, DriveSmart and CDDrives, it uses serial pictures rather than video footage of driving scenes. There are three different phases within the application. The “Pre-Test” presents various sequences of pictures, wherein the user has to click on the areas he believes he should glance at to perceive possible risks. The user gets no feedback in this phase. This is followed by a “Training”, in which the sequences are repeated. However, this time, the sequences are preceded by a short explanation of the following situation, employing a bird’s view on the scene to emphasize certain critical aspects. The sequences are repeated if the user misses to click a relevant area in the photo sequence. Finally, there is a “Post-Test”, which is similar to the “Pre-Test”. RAPT has to be seen as scientific tool rather than an actual product. So, it lacks the visual appeal of the other applications described. However, at the same time, it has been thoroughly researched (e.g. Fisher, Narayanaan, Pradhan, & Pollatsek, 2004; Pradhan, Fisher, & Pollatsek, 2005; Pradhan, Fisher, & Pollatsek, 2006). Trained participants are reported to more often fixate relevant areas in a simulation compared to untrained participants. This effect was found directly after the training, but also four days later. In the field, positive effects on glance behaviour and hazard detection have been found, too (Pradhan, Fisher, Pollatsek, Knodler, & Langone, 2006).

2.5 Summary

The applications reviewed here share all some similarities, but are also quite distinct in various aspects. In general, they are without a doubt of higher physical fidelity than any textbook. This is largely a result of their use of realistic, dynamic depictions of traffic situations. Also, most of them have a problem-based approach to structuring the knowledge to be taught. Another advantage is the higher level of interaction with the content by means of clicking at hazards or commenting on traffic scenes. Feedback is often provided based on the answer given or reaction shown, exploiting the opportunities of CBTs to generate an adaptive
content. However, the range is very broad here – there is simple “correct/false” – feedback as well as additional instructional information or even the depiction of consequences of the participants’ answer of choice. Most of them also try to generate some motivating appeal by using age-specific content and language. Overall, these tools show that an improvement of the current practice of driver education is possible. Theoretical analysis and experimental research provide evidence for an additional contribution of CBTs. Still, as of now, it is impossible to predict whether such a CBT can be useful in any institutionalised system of driver education. The systems in the US and Oceania are quite different from many of the European approaches. Also, the transfer of content is hardly possible from one country to another, even within Europe. Therefore, we developed a CBT that is supposed to have a safety effect within a central European (e.g. German) context. It has to be emphasized that the application’s main purpose is research. At the current stage, it is not thought of as a product that might be distributed and marketed. It is rather considered a useful device in the search for learning effects that might be caused by CBTs in driver education.

3 MULTIMEDIA TRAINING PROGRAM “VORFAHRT”

3.1 Background

The computer based cognitive skills training presented in this paper has been developed on the ground of the aforementioned theoretical underpinnings, incorporating ideas taken from the described tools available. At the same time, there exist structural constraints in the licensing process that contributed to the shape of the tool. In Germany, driver education is heavily regulated. There are lessons in which theoretical knowledge is taught followed by an examination, as well as a minimum number of practical driving lessons that need to be completed to be permitted to take the driving test. Neither parts of the theoretical nor the practical teaching are supposed to be replaced by multimedia applications (as opposed for example to the Netherlands, where driving in a simulator in part replaces practical lessons). Applications are rather intended to facilitate the learning process that is already there, following Mayhew’s (2007) call for the improvement of the practices that are in place.

The general idea was to fit the application somewhere in between the theoretical and the practical lessons, allowing for a better transfer of the abstract knowledge taught in the classroom to the practical on-the-road experience. Haworth and colleagues (2005) argue that “there is generally less need for physical resemblance (physical fidelity) (…) in the early stages of learning than on later stages” (p. 5). Considering the classroom teaching as appropriate for the very early stages of learning to drive, the adoption of CBTs (which offer a learning environment that is richer in physical resemblance of the real driving situation, but is still far from being real) appears to be the logical next step to take before letting learner drivers finally get into a real vehicle.

3.2 The Program

The application consists mainly of three parts: (1) a pre-test on theoretical knowledge, (2) an instructional phase, and (3) the actual training. The pre-test contains questions taken out of the German theoretical exam. Although data are recorded, the main objective of this pre-test is not the assessment of previous knowledge, but the activation of this knowledge in the participant. In the instructional phase, the relevance of the training and its contents are pronounced. Knowledge that is essential for the successful completion of the training is given, which concerns the operation of the application as well as important previous knowledge connected to the issues the training tries to address.

The actual training uses short clips of traffic scenes, embedded in a Flash environment, to transport information. Instead of using real life video footage, we generated artificial animations that in many aspects are comparable to a driving simulating, however with much higher visual quality (see Figure1 for an example). We chose to do so because that strategy
allowed us to have absolute control of any variable we might want to manipulate in the video. So, what we lose in terms of realism, we gain in opportunities for producing virtually any situation we might think of. The video sequences are 50-70 sec in length. The participants watch them from the driver’s point of view. They are instructed to observe the evolving situations as if they were driving. This experience is supported by a “navigation system” which informs the “driver” about the route (e.g. “turn left”).

Figure 1: Screenshot out of the training application.

Scenes were constructed to reflect various aspects of the driving task. Critical information appear in areas that are vertically (e.g. something ahead in the driver’s lane) or horizontally (e.g. something on an intersecting road) distant, as well as in the mirrors. Examples of potential hazards are a cyclist that has to leave the bicycle lane because of a roadblock there, or a pedestrian that tries to catch a bus on the other side of the road. Driving tasks that are displayed include car following situations, overtaking situations, turning right and left, or crossing intersections. An important aspect is the repetition of driving situations and potential risks. So, although there is no scene that is displayed twice, the elements that constitute the scenes are repeatedly trained.

The training is composed of two different sessions, both containing 13 video sequences. Each of the video sequences contains two or three questions. The scenes are stopped at various positions and the questions are presented. Most questions are in multiple-choice format, some also require the participants to mark certain relevant areas in the stopped video. Depending on the correctness of the answer given, there is feedback, followed by either the continuation of the sequence or the repetition of the previous segment of the scene (in case of a wrong answer). Questions in the first session deal with the sole observation of the traffic environment as well as the understanding and prediction of the situations. In the second session, the format is more standardised. Once a scene is stopped, the first question is always: “Is there a need for action?”. If so, this is followed by a multiple choice question asking what this action would be, followed by a third question on why this is necessary. At the end of each
session, the CBT gives a general feedback on the participants’ performance, indicating issues (e.g. “scanning left and right”) that should be addressed in further training.

4 EVALUATION

Regardless of a theoretically sound design of the training application, an experimental evaluation is necessary to assess its effectiveness. However, in doing so, we face various problems. Driving and gaze data, gathered in the field as well as in the driving simulator, enormously vary both between and within subjects. Also, a within subjects design by testing participants in the simulator before and after the training is not a proper approach, as (a) the first testing session might serve as a training for the second one, making any differences found hard to interpret, and (b) additional training at the driving school might occur in between the testing sessions. Thus, one has to opt for a between-subjects-design (regardless of choosing to use a simple between groups comparison or to compare before-after differences for both groups), which increases the variance. In addition, considering the learning curve, which is very steep at the beginning of the course of skill acquisition, it is nearly impossible to hold the recruited subject sample of learner drivers totally comparable in its level of training, even with the strictest criteria for participation.

Still, we believe an experimental assessment needs to be undertaken to provide evidence of the applications capabilities. Only then it is possible to give recommendations about further uses of CBTs in general and this application in particular. At the same time, it is also necessary to investigate specific mechanisms that may or may not be helpful in the course of skill acquisition, to further improve the programs’ effectiveness. In a first step, we conducted a simulator study to test the applications’ general effects on gaze and driving behaviour.

4.1 Method

The programs’ evaluation was planned to test both the general effectiveness of the training application and the specific effects of the multimedia application compared to a text based instruction. As it is argued that the specific characteristics of CBTs might provide additional opportunities, it has to be proven that this training is not only superior to a “no training” condition, but also a “non computer based training” condition. We therefore tested three groups of participants that received either the CBT, a paper based instruction that was similar in content to the computerized version, or no training at all.

The training session for the CBT group consisted of the two different sections that where implemented in the application, separated by a break of 15 minutes. For the “paper based instruction” group, there also was a training session in which the participants worked through the material that was constructed to closely resemble the content of the computerized version. Both groups also completed questionnaires on demographic information as well a test on previous theoretical knowledge. The control group only had to show up for the simulator test. For those participants, questionnaires and the pre-test were placed before the simulator drive.

The testing session took place two days after the initial training. The examination was conducted in a static driving simulator (STISIM simulation environment), which consisted of a full size vehicle (BMW 350i) with force feedback steering and projection on three screens that offered 135° horizontal visual field. Scenarios included urban (one or two lanes per direction) and highway (three lanes per direction) drives. Within the scenarios, we placed various events that can be described as moderately critical. Whereas those events required some kind of action to be taken to avoid a collision, participants had sufficient time to react appropriately. The events were modeled in part quite close to the situations that could be encountered in the training application to assess near-transfer of the acquired knowledge and skills. Other events that had not been presented in a similar form in the application were introduced to investigate far-transfer. The obtained data include gaze (via eye tracking) and driving data.
4.2 Results

57 participants took part in the evaluation study. All of them were learner drivers that had completed the theoretical part of the education, but had minimum driving experience in practical lessons. None of them was in possession of a license to ride a motorcycle, as we believed that in such cases the cognitive skills we try to address would have been developed already.

When analysing the data, we had a look at each of the particular scenarios. For each one, we defined an “unspecific hazard indicator” (e.g. a petrol station) and a “relevant area / object” (e.g. a lead vehicle that might enter the petrol station) to be able to assess possible changes in glance behaviour. When analysing twelve different driving simulator situations, we found evidence for CBT participants to be faster in fixating the unspecific hazard indicator in the traffic scenery than the control group in nearly all of the situations. Furthermore, the CBT group clearly outperformed the paper based training group, which produced even worse results than the control group. A similar effect can be found for the “relevant area / object” metric. Again, CBT participants reacted fastest, paper based training participants were slowest. There appears also to be a tendency for CBT participants to earlier complete a sequence of fixations from the unspecific hazard indicator to the relevant area / object. These results strengthen our claim that the CBT can indeed be effective. More specifically, these results seem to indicate that the training generates some deeper understanding of the traffic situations. Especially the fixation sequence from the unspecific hazard indicator to the relevant area / object is proof that CBT participants not only change their overall glance behaviour, but are also able to make proper inferences from what they perceive. It can be argued that they appear to be faster in understanding what the hazard indicator means for the situation, allowing them to react quickly with the appropriate gaze strategy.

For the driving data, we defined measures for each scenario that might be linked to some form of reaction by the driver. Taking the foot off the throttle, braking or swerving are just some of the variables that were analysed, depending on the respective scenario. For some scenarios, there appear to be tendencies of CBT participants to be reacting faster to a potential risk. The number of crashes for several situations is also lowest the CBT group. However, data are quite noisy, so evidence for an immediate impact of the training on numeric driving data is hard to come by with. This is somewhat disappointing, however not uncommon in this field of research.

5 OUTLOOK

The CBT developed within our project appears to be a promising candidate for improving driver education. Especially gaze behaviour appears to be a good indicator for the positive effects the training can have on learner drivers. However, further investigation into the processes underlying these effects is necessary. As the participants’ engagement in traffic relevant information within the CBT is achieved mainly by asking multiple-choice questions, the CBT itself gathers interesting data, too. Assuming that the CBT teaches skills that separate novices from experts, an analysis of the participants’ answering patterns might further strengthen our claim that the application’s content indeed comprises relevant knowledge. A comparison to an expert group going through the training will be conducted as well. There will also be a group that will only work through the first session of the training, and then will be tested. This will allow us to better quantify the additional impact the second session has on driver performance. As the second session differs in the way questions are put, requiring some sort of transfer from the learner, one might expect interesting effects and further information here. The results will be used to gain a better understanding of the specifics of the effects our training generated, to finally optimize and enhance the CBT.
6 ACKNOWLEDGEMENTS

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REFERENCES


THE NEW ROAD SAFETY PROGRAMME FOR COMPREHENSIVE SCHOOL OF LITHUANIA: THE DEVELOPMENT AND IMPLEMENTATION

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ABSTRACT
Lithuania is one of the most dangerous countries for vulnerable road users in Europe. In order to reduce the number of road accidents and the wounded road users all possible strategies are involved. Education is not an exception. However, till the year 2007 the road safety education in the Lithuanian schools has been provided without any programme. The new road safety programme for comprehensive school (1-8 grades) was developed in the years 2005-2006. Theoretical grounding, structure and the content of the programme are presented in this article.

1 INTRODUCTION
Over 1000 young people under the age of 25 years are killed in road traffic crashes around the world every day. Road traffic injuries are the leading cause of death globally among 15-19-year-olds, while for those in the 10-14-years and 20-24-years age brackets they are the second leading cause of death. Most young people killed in road crashes are vulnerable road users – pedestrians, cyclists, motorcyclists and passengers of public transport (Toroyan and Peden, 2007). Pedestrians are an extremely vulnerable road user group, largely due to their lack of protection and limited biomechanical tolerance to violent forces when impacted by a vehicle (Congiu et al., 2008). Lithuania is one of the most dangerous countries for vulnerable road users in Europe. Children are especially vulnerable in the environment of the roads. Injuries received during the road crashes become the main cause of children’s death in Europe and other developed countries of the world (Lam, 2001; Langley, 2001; UNICEF, 2001). Among other European countries Lithuanian is characterized by the highest number of injuries of the pedestrians received during the road crashes. Lithuanian National Health Programme states that road crashes and injuries in Lithuania can be called a national disaster. Every member of the society is a participant of the road traffic. The level of safe traffic in the country depends on person’s behaviour. The reason of many road crashes is the insufficient competence of road users. More attention is paid to education of health and behaviour changing, scientific researches.

After the analysis of the scientific researches of the 20th century in the West Europe, Scandinavia, North America and Australia it became clear that all practically applied children’s road safety educational programs were characterized by a low level of efficiency, if the efficiency is considered to be the changing of pupils’ behaviour at the roads (Rothengatter, 1981; Pearn, 1985; Antaki et al., 1986; Gregersen & Nolen, 1994; Thomson et al., 1998). According to T.Rothengatter (1981) it would be incorrect to assess children’s road safety education efficiency by other criteria than changes of behaviour in the road traffic. The
author of this article approves this opinion. I.Pless and L. Arsenault (1987), J.A. Thomson et al., (1998), I. Lubman (1999), P. Björklid (2003) note that children’s road safety educational programs are not only insufficiently effective, but do not also correspond to the changing conception of children’s education and educational practice. Criticizing the children’s road safety educational programs of the European countries I.Pless and L.Arsenault (1987) pay attention to the fact that these programs are prepared not in the educational institutions, but in the laboratories and institutions of transport research by specialists of not educational field. Thereby, the road safety education becomes particularly theorized, orienting a teacher towards a direct verbal conveyance of demands and knowledge about the safe behaviour. The authors advise not to make children “to behave properly but to motivate their favourable attitude towards the safe traffic basing upon rational benefit, what makes a greater influence upon individual’s decisions and behaviour”. It is claimed, that “the children should be provided with such knowledge and abilities, which would make conditions to take better decisions” (Pless & Arsenault, 1987). I.Lubman (1999) compares the experience of children’s road safety education to the conveyance of religious dogmas, which are essential to be believed in and to be kept faultlessly. According to the author’s opinion such road safety education could not be effective and does not correspond with the changed attitude toward a child, person, pedestrian and education. According to P.Björklid’s (1997a) opinion one should try to get children interested in the road traffic environment by developing children’s opportunities but not trying just to control their behaviour”. Basing upon J.Piaget’s researches, P. Björklid claims that “children’s road safety education should be oriented toward active observation of the traffic environment, its study, what would create conditions better to realize both local and global traffic – the problem, reason and outcomes. According to the author’s opinion, in the process of road safety education one could invoke the real traffic environment during the pupils’ way to school”.

At the joint of the 20th and 21st centuries the main attention is concentrated on the traffic environment and its reconstruction regarding the demands of undefended traffic participants and refusing the idea to make people adapting to the environment created to cover the needs for transport. According to the psychology and education specialists’ opinion children’s road safety education should not be denied but it should be changed. P.Björklid (1997a) approves the reconstruction of the traffic environment and claims that the children’s road safety education cannot be the only method to reduce children’s injury rate in the accidents and we should give the young generation the best education in the field of the safe traffic. Assessing the new road safety strategy for young citizens directed towards the reconstruction of the traffic environment, J.A.Thomson, A.Tolmie, H.C. Foot and B.McLaren (1998) believe that this perspective is too optimistic; and the assessment of the road safety education opportunities is too pessimistic. According to authors’ opinion, “the modern assessment of aims and methods of pedestrians’ road safety education is necessary, basing upon the analysis of problems, which should be solved by the pedestrians in the traffic environment”. According to the author of this article, the restriction of person’s opportunities to attend his/her and other people’s safety in the traffic environment by disrupting the competencies of road safety would be inhumane and dishonest.

Till the year 2007 the road safety education in the Lithuanian schools has been provided without any programme. The road safety education has been based on the Traffic Rules, objectivistic methodology and behaviourists’ attitude to the educational process. Primary school programme, which have been operating till 2003, indicated that the result of
safety education was good mastering of traffic rules. Verbal teaching methods - explanation, narration and discussion – were dominating. The place of learning was a classroom at school. Such teaching model was both ineffective and did not correspond to the new conception of learning both nationally and internationally (Vilkonis, 2003).

After the analysis done in the years 2000-2004 of world experience, cultural traffic peculiarities in Lithuania, the reasons and factors of accidents, theories of behaviour and education the experimental model of children’s road safety education was created, which was tested in the educational practice in the years 2003-2004 (Vilkonis, 2005). The aim of this article is to define the competencies of road safety and their content in the educational process, to present the road safety programme for comprehensive school of Lithuania prepared on the basis of the mentioned researches and being implemented since the year 2007.

2 THE CONCEPT OF ROAD SAFETY COMPETENCE

For a long time the children have been taught the road safety by paying the main attention to the knowledge. The knowledge is very important, however, it does not always determine the change of the behaviour. The road safety education aims to reduce the number of people injured in the accidents. In other words, it aims to reduce the vulnerability of traffic participants, or to increase the resistance of traffic participants to accidents. The knowledge should be applied in everyday life. It should be practical and useful. It should help protecting a person and surrounding people in the traffic environment. The statistics of accidents shows that the exemplary observance of the Traffic Rules does not secure person’s safety; especially, if speaking about the pedestrians. The majority of the pedestrians in Lithuanian suffer from the violation of the Traffic Rules by drivers. The most dangerous place for the pedestrian is the zebra crossing (Joly, Foggin & Pless, 1991; Björklid, 1997; Ekman & Hyden, 1999).

The road safety knowledge should help not only to follow the defined requirements of traffic behaviour, but also to protect from the actions of the other traffic participants – both deliberate violation of the Traffic Rules and mistakes. It is quite important to apply the knowledge in everyday life. In order to apply the knowledge in traffic environment it is essential to believe in its usefulness and to be able to use it. If talking about the ability and desire to apply the knowledge practically in everyday life situations we should talk not only about the conveyance and accumulation of the knowledge, but about the competence training. Therefore, if we want the road safety education to influence the behaviour in the traffic environment, we should set a task – not only to provide the knowledge about the road safety, but to train the road safety competence. Although, some authors used the notion of qualification, competence when talking about the road safety education; however, the content of the road safety competence has not been defined. The term competence was used by Thomson, Tolmie, Foot and McLaren (1996), OECD (1998), Pitcairn and Edlmann (2000) in the papers concerning the pedestrian road safety questions in the XX c. P.Björklid (1997), Whitbread and Neilson (1998) used qualification term.

The notion of the competence is used differently. The competence can be understood as a person’s characteristic, ability, as a power granted to a person to solve or do something, as an expression of a certain specialist’s activity. If talking about the road safety competence one means person’s characteristic, ability. The notion of the competence was developed at the end of the 20th century; besides the knowledge and ability, the attitude was included in its
structure. It was motivated by new research results, which revealed the aspect of development of social and cultural abilities, and dissatisfaction of the behaviouristic competence conception, which has dominated earlier (Haris et al., 1995). Favourable attitudes regarding the road safety and seeking the changes are underlined by I.Pless and L.Arsenault (1987). T.Hyland (1994) includes the problems solution in the notion of competence. According to C.Chapell (1996), the competence could not be finished, stable, acquired for a whole life and related not to the learning, but more to the process of personality development. Taking into account the dynamism and indeterminacy of the real life situations what aggravates the control of behaviour according to the aim provided beforehand or some rules, the Theory of Constructivism suggests to motivate the reflection and the contemplation of one’s knowledge and abilities and their assessment according to the fact how they satisfy person’s demands, opportunities and situation; to improve the acquired competence and add it with useful knowledge (Hyland, 1994; Hotkinson & Issitt, 1995). The road safety competence could be defined as the ability to move safely in the traffic environment and person’s active attitude seeking to reduce the influence of the risk factors and accidents; it means a certain level of abilities, which is achieved by every person in the process of socialization by accumulating the experience in the traffic environment and influenced by various social-cultural environmental factors. The road safety competence is – on a certain level:

- **Knowing** what risks can be faced in the road traffic environment, how to identify them in time, to react to them; what main risk factors increase pedestrian’s vulnerability and how to reduce their influence;
- **Ability** to identify the source of risk on the road, to predict it and to behave adequately using the available knowledge, skills and information form the road traffic environment;
- No less important is the favourable attitude towards oneself as an active actor of the road traffic environment and person’s responsibility for his/her sense of safety. This characteristic is underlined by Whitbread and Nelson (1998) as one of the factor of pedestrians’ efficiency.

Here we should return to I.Pless and L.Arsenault’s (1987) offer not to make children to behave “properly” but to motivate their favourable attitude towards the road safety basing upon rational benefit, what makes a greater influence upon individual’s decisions and behaviour”. It is claimed, that “the children should be provided with such knowledge and abilities, which would provide the conditions to take better decisions”.

For the most part, the modeling of the structure and content of the road safety competence is based on the Psychological Decision Theory (Kozielecki, 1979). Very important factor was also considered – the necessity of lifelong learning, typical for the road users. The rules change, therefore, the road traffic environment also changes. It is not enough to learn once for a whole life. A person must be able to adapt to the changing living environment, learn to apply the known models of the road safety to new conditions or to create the new models if the old ones do not provide safety. The road traffic environment can change not only in the current of time but when changing the place of residence – the world is becoming less and the people’s mobility increases. Therefore, on of the most important competence components should be the creativity. It is the ability to create by one’s the new models of behaviour regarding the changing environment and source of risks. If speaking about lifelong learning, it is relevant to do this without teacher’s help. Therefore, the
learner’s independence is especially important. The content of the road safety competence is presented below:

- Information in the long-term memory on the basis of knowledge, creating the prerequisites for realizing the traffic environment, order of movement, requirements of Road traffic code, risk factors in the road traffic environment; realizing and identifying the sources of road risks, to react properly to the noticed risks;
- Models of safe behaviour are grounded by algorithmic strategy of solutions kept in the long-term memory with the help of visual and verbal schemes and increasing the reliability of decisions in the traffic environment;
- Ability to get enough useful information from the traffic environment – to notice the sources of risks in time, to identify dangerous road traffic situations, to predict accident situations;
- Ability to evaluate adequately the situation form the traffic environment using the information from the long-term memory and to create an adequate image of road traffic situation (“task”); the creation of adequate image of a task is a half way in taking the decision;
- Ability to act adequately for a certain information and created image of a road traffic situation (“task”): to take the right decision and implement it (observing the environment and one’s behaviour, evaluating the information from the environment, correcting the image of task and behaviour);
- Ability to improve the road safety competence, to correct the known models of the road safety regarding the changes of the road traffic environment;
- Safe behaviour motivation, which would be secured by person’s sense and efficiency of responsibility for his/her and surrounding people’s safety in the road traffic environment – to believe in the opportunity to influence one’s safety in the road traffic environment.

The research in Lithuania have shown rather low efficiency of pupils as the traffic participants and the transfer of responsibility for one’s safety to other people – state, police, drivers (Vilkonis, 2004). That proved the importance of inclusion of efficiency and responsibility for person’s and surrounding people’s safety education into the competence content and the importance of education in the childhood.

1 The concept of the development of road safety competence at school

In what way the study process should be organized in order to educate the road safety competence? It is not the same as teaching the Road Traffic Code. The fact that children develop independently by investigating the surrounding living environment (Björklid, 1997b), the intellect develops on the basis of constructive activity and children’s activity, environment investigation and experimentation are necessary for the processes of assimilation and accommodation (Piaget is quoted from Tuckman, 2002) determines the problematic character of the road safety competence education, observation of the social-cultural environment and especially the objects and phenomena of the traffic environment, not complicated research in the study process. No less important is the orientation to a child, his/her problems, i.e. the problems noticed and experienced by a child. L. Vygotsky’s Cultural Historical Activity Theory, J.Bruter’s Discovery Learning Theory and A.Bandura’s Social Learning Theory are very important in the process of the road safety education. The works of L. Vygotsky, J.Bruner and A.Bandura are interdependent, because all these theories recognize the influence of social environment on person’s formation. Although, L. Vygotsky
and J. Bruner agree with the importance of child’s natural maturation on his/her intellectual
development revealed by J. Piaget, they accept that this fact should be considered in the
process of education. However, according to them, the organization of educational process
has the crucial importance, i.e. the education does not follow the development, but the
education determines child’s intellectual development (Bandura, 1974; Bruner, 1996;
Conway, 1997; Солсо, 1996; Тукман, 2002). A. Bandura’s Social Learning Theory claims
that a person learns by observing the behaviour of other people. Behaviour models,
demonstrated consciously or unconsciously, are memorized and applied if people, who
perform these models, achieve high results and are successful. In this case the Social
Learning Theory explains how naturally the young generation adopts the elder generation’s
models of drivers’ behaviour. In this case the theory not only helps, but also motivates to
organize the educational process of the road safety competence in a way to reduce the
influence of social environment on children. The model of the children’s road safety
education advises to limit negative influence of social environment and to invoke the social
environment as a study environment and means.

J. Bruner’s Discovery Learning Theory underlines the understanding of the study
subject structure, educational activity as a source of essence understanding and the
importance of discussions in the educational process (Dembo, 2003). This educational model
is especially effective when the education is related to the problem solving. Educational
process organized according to this theory gives children an opportunity to identify the
problems in the surrounding environment by investigating and experimenting, they look for
the answers to their questions, put forward hypotheses and test them, summarize the data of
observation experiments by comparing the facts, discussing, formulating conclusions, which
become the new knowledge. It is considered that the truth discovered by self is better
memorized in the knowledge system, and later would be better applied in solving the
educational and life problems (Conway, 1997). Children are motivated to use actively their
intuition, imagination and creativity. In such educational process children create the
knowledge, which should acquire, but do not take it from a teacher or a textbook (Тукман,
2002, p.147). The inductive thinking and teacher’s help in research organization are typical
for this educational model. In the process of children’s road safety education this model is
expressed by the fact that children with teacher’s help create their own knowledge about the
safe pedestrians’ traffic system basing upon the analysis of the data accumulated in the
research process and conclusions formulated in the summary. The traffic environment
problems are identified during the researches (observation, questionnaire, analysis of the
documents, arithmetic actions); the hypotheses about the means of the road safety are put
forward, tested and corrected in the modeled environment. The road safety models created by
children are tested by analyzing the causes and factors of the accidents, in which their
contemporaries-pedestrians were injured; by observing the behaviour of other pedestrians
and their own behaviour in the real traffic environment; by discussing the analysis of
observation results and on the basis of generalization.

Taking into account the fact that all result of the 20th century researches show that the
only effective road safety education environment is a real road traffic environment it should
be the main educational environment. However, regarding the fact, that during the lessons
there are no opportunities to do it at all or to do it often, a real road as an educational
environment is used not during the lessons. The specific of the road safety education is in the
fact that the real road traffic environment as an educational environment and laboratory is
also a living environment, which is available every day. Every day children accumulate there their experience. It is important to control this process pedagogically, reaching the assigned aims.

It is also important to underline that this model of road safety education can be applied only in the case when the pupils as the pedestrians’ mobility is high enough. If the children are often and usually driven everywhere by car, the result will be difficultly to achieve. The training is important for abilities education. Pupils as the pedestrians’ mobility in Lithuania is high enough – 77% of pupils go on foot to school and 83% of pupils go on foot back from school. Some of them use public transport. Only 11% of 7-8-year-old pupils are accompanied by the adults. Back from school only 6% of pupils of the same age are accompanied by the adults (Vilkonis, 2001, 2003).

3 THE ROAD SAFETY EDUCATION PROGRAMME

The aim of the road safety programme is the creation of conditions for pupils to develop the road safety competence thinking about the roles of all traffic participants – pedestrians, passengers and drivers. A driver should also be educated from childhood by relating this process closely to the programme of hones education. The education of a driver in the comprehensive school must not be wrongly understood as a process of driver’s preparation by studying thoroughly the ‘Traffic Rules for drivers. The road safety education in the comprehensive school should motivate a driver trained later in a Driving school to use a car as safely and honestly as possible regarding other traffic participants. The education of valuable attitudes is one of the programme tasks and is related to the educational programme for harmonious development. The values, abilities and content foreseen in the programme are presented and commented below in the Table 1, Table 2 and Table 3.

Table 1: Valuable attitudes ant their development

<table>
<thead>
<tr>
<th>Values</th>
<th>Comments and didactical notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respect to life, responsibility for life conservation</td>
<td>The attitude to respect and protect a life (and not only human’s life) must be educated in the process of the road safety education. A lot of animals are killed on the roads, among them there are pupils’ pets. The education of valuable attitudes is not an easy task. This is a long-term process. It is useful to appeal to pupils’ experience and the experience of their families. The method of discussions is particularly effective when using the valuable attitudes. A discussion can give a rise to doubt one’s convictions and this is one step towards changes.</td>
</tr>
<tr>
<td>Respect to other traffic participants irrespectively to their age, sex, race, social status etc.</td>
<td>Traffic behaviour is also influences negatively by such factor as a different attitude towards other traffic participants, exclusive assessment of certain groups, their underassessment. Disrespect demonstrated by driving men towards driving women is noticed in Lithuania. The dominating disrespect to the pedestrians especially the elderly people is easily noticed. This is expressed by negative emotions and solutions of high risk level. The reasons of this phenomenon should be analyzed in the educational process, basing upon pupils’ personal and their families experience, opinions, values.</td>
</tr>
<tr>
<td>Creation of a safer road traffic environment</td>
<td>Safe behaviour should be understood not only as a way of self-protection but widely as a participation in safer traffic environment creation. Every traffic participant by his/her behaviour affects in a certain way the functioning of the system “Traffic participant – transport means – road – traffic environment”. Along the education of this conception, one should try to educate the favourable attitude to participate actively in creation of the safer traffic environment. First of all, by one’s behaviour, and later to participate actively in public discussions considering the prepared laws, road development projects etc. The education of this valuable attitude is closely related to patriotic education. In order to educate patriotic activity solving the traffic problems one should organize such road safety action. It can be directed towards school community, workers of school micro-district, place of residence and responsible institutions.</td>
</tr>
<tr>
<td>Responsibility for self-safety in the road traffic environment</td>
<td>A person who transfers responsibility for his/her safety to other people, gives too little energy for reducing self-vulnerability by his/her actions. Therefore, the actualization of personal responsibility for self-safety and education of attitude to take care of self-safety from childhood is very important in order to reduce the vulnerability of traffic participants, especially the pedestrians, passengers and bicyclists.</td>
</tr>
<tr>
<td>Environment protection and rational consumption of resources</td>
<td>The exhaust gases become the main source of atmosphere pollution. The use of public transport and bicycles in everyday life is one of ways and objectives to protect the environment in Europe. Teaching the road safety is a part of general education. Therefore, it is important not only to learn self-safety but to see the range of problems widely. For example. When blocking the traffic the pedestrians could think about the increase of pollution at the moment of car stopping and racing. It would be possible to protect the environment, oneself and surrounding people by keeping the larger distance in the cars flow. The analysis of the environment would be useful in the implementation of the programme. Some researches could be organized in cooperation with the teachers of the natural sciences. The researches would show the pollution of school environment. The observations on the way “Home – school - home” could be organized.</td>
</tr>
</tbody>
</table>

The main attention in the competence structure is paid to the ability to apply the acquired knowledge.
<table>
<thead>
<tr>
<th>Abilities</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to predict dangerous traffic situations</td>
<td>In order to predict dangerous traffic situations it is necessary to know the most frequently repeating situations and main factors, which determine the appearance of dangerous situations. This knowledge allows predicting situations. In order to educate the ability to use this knowledge, children should not only acquire the knowledge, but have the practice in predicting dangerous situations. The method of modeling can be used.</td>
</tr>
<tr>
<td>Ability to notice and assess the sources of risk in time</td>
<td>The education of this ability is grounded by knowing the main risk sources in the traffic environment and training the practice of their search in the traffic environment. The video of traffic environment and observations on the way “Home – school - home” could be used.</td>
</tr>
<tr>
<td>Ability to create an adequate image of road traffic situation</td>
<td>According to the Psychological Theory of Solutions the creation of adequate image of situation is a half way to take a right decision. One situation can be evaluated and seen differently by different people. The image of situation is subjective and depends on the experience a person has (including the knowledge). The more the image of situation corresponds to the real situation, the more opportunities the traffic participant has in taking the right decision and avoiding the negative outcomes. This ability mainly depends on the abilities described above.</td>
</tr>
<tr>
<td>Ability to behave properly: to take a right decision and to implement it</td>
<td>The peculiarity, which excludes the road safety education from other fields of education, is that the theoretical knowledge is crummy without the ability to use it in everyday life experience. Even if a child assesses properly a traffic situation and takes a right decision in time, this decision must be realized efficiently. In this case a child needs the psychomotoric skills, which are developed in practice.</td>
</tr>
<tr>
<td>Ability to develop independently the road safety self-competence</td>
<td>If speaking about the road safety education it is necessary to underline that there an important role is plaid by the necessity of whole life learning. Traffic environment changes constantly. Therewith, changes the character of dangerous situations. Today’s pupils should be able to adapt to constantly changing traffic conditions, recognize new sources of risk, learn to predict new risk situations, change and modify earlier known and used road safety models and create the new ones regarding the changed environment and new sources of risk. This should be done by children independently, without teacher’s help. The ability to improve independently the road safety competence becomes relevant when changing the place of residence. People’s international mobility increases and people who changed the living place belong to the group of the most vulnerable traffic participants.</td>
</tr>
</tbody>
</table>
The content of the road safety education is conditionally divided into four fields. One of them is the Environment studies. It is the integral field realized together with other fields as a principle and the means of educational process organization.

Table 3: The content of the road safety education and didactical recommendations

<table>
<thead>
<tr>
<th>Fields</th>
<th>Comments and didactical recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>System „Man – Road – Vehicle – Road Traffic Environment“ (M-R-V-RTE), Road Traffic Code</td>
<td>The field is devoted to recognize the traffic as a sensitive and unstable system which harmony depends on all interrelated components of the system and especially on the particular decisions of the traffic participants on the road and the quality of these decisions practical realization, attitudes and values, character of relations with the environment and other people. Natural sciences as an integrated field of the road safety education content should be directed towards the study of both physical and social environment. The context, real traffic situation in the place of residence is especially important in the process of the road safety education.</td>
</tr>
<tr>
<td>Conflict situations in the system M-R-V-RTE, their reasons and outcomes</td>
<td>The field to understand the dangerous situations and accidents as a certain conflict between traffic participants. Here it is important to reveal the role of the road users for harmonious functioning of the system. The natural sciences could be expressed by statistic information expressed by various means, analysis of comments of certain accidents reasons in the periodical press. The experience of pupils, their family members and relatives is also very important educational material. Contextuality, constant contact with the real life is one the road safety education peculiarities, which could be called even a principle.</td>
</tr>
<tr>
<td>The implementation of the road safety; main strategies (directions) and means of activity</td>
<td>The field to understand the social affords to increase the road safety, main strategies of the road safety implementation (improving the transport means and the roads, improving the traffic order and controlling it, improving traffic participants’ road safety education), main means of the road safety (passive and active safety), pedestrians and bicyclists’ models of safe behaviour. The wider conception of the road safety implementation is very important because a pupil should see his/her attempts in creation of the safer traffic environment context. One should be educated to consider the means of the road safety implementation as a system where every action must be in harmony with other actions. The range of problems of pedestrians, passengers and non-motorized transport means drivers’ road safety regarding the age group is very important here. Nature sciences are perfectly integrated in this field. In this case it would be relevant to observe the behaviour of the traffic participants, i.e. the pedestrians, and drivers’ behaviour from the pedestrians’ point of view. Real road traffic environment, real road traffic situation in the living place, real road traffic participants and their interrelations are important part of the educational material. It is very important to analyze the road</td>
</tr>
</tbody>
</table>
traffic participants’ behaviour in the road traffic environment as the people’s behaviour, to notice the peculiarities and drawbacks of this specific communication, to find how to behave in order to reduce the risk of disorder of the system harmonious functioning. When creating the road safety models one should remember that the disciplined observance of the Traffic Rules instructions does not guarantee the safety on the personal plane. Someone cannot follow these instructions or be wrong. When seeking the road safety it is important not only to follow the defined order but try to avoid the negative outcomes, which appeared due to disorder made by other traffic participants. The models of road safety should provide conditions to avoid an accident due to risky behaviour of other traffic participants – conscious or unconscious. Sometimes it is quite difficult to orient in the traffic environment, especially for the drivers, because when the moving speed increases, respectively increases the speed of information received from the environment. This needs the quick analysis of received information. The time for situation assessment and taking the right decision reduces. The right decision must also be successfully implemented. A lot of objective and subjective factors limit driver’s ability to do all this perfectly well. Therefore, it is quite difficult to avoid mistakes. Therefore, the ability to predict the behaviour of other traffic participants and their mistakes is one of the conditions of the road safety. It is recommended to use tasks for thinking with limitation of time for task performing; also task performing when running or standing (in a classroom). Comparative analysis of the results. Such tasks should help pupils to understand that hurry on the road is a real problem.

| Environment studies (basic research of traffic environment and problems regarding the level of pupil’s abilities) | Integral field realized together with other fields is important when educating observation, ability to orient in the traffic environment, assess and evaluate, develop actively the knowledge about the road safety. The separate topic or lesson is not given to this field. The studies about environment are implemented through environment observation, introspection, questionnaire, analysis of statistic data and texts, comparison and classification. Such studies give a lot of useful educational material from the real life, real pupils’ living environment and specific traffic environment with road traffic problems relevant for pupils. |

The road safety education programme is related to honest education (respect to life and other traffic participants, the contribution of interests of insignificant persons’ for the road safety of the surrounding people’s welfare etc.), social education (partnership, solidarity; communication and cooperation when solving the problems; constructive solution of problems etc.), civil education (active participation when solving the road safety problems in the living environment and country by preparing the new laws etc.), natural science education (apprehension of nature phenomena and laws relevant for road safety) and education of informational abilities (ability to get information in the traffic environment and
various sources of information, to use it, to give information to other traffic participants). Therefore, it is recommended to find the opportunity to cooperate with teachers of other schools.

REFERENCES
Langley J. (2001). International comparisions: we need to know a lot more. *Injury Prev.*, 7, 267-269
Safety of Vulnerable Road Users. (1998) . OECD. Unclassified DSTI/DOT/ RTR/RS7 (98)1/ FINAL


ABSTRACT
The rapid rise in motorization, road improvement, and lack of road safety education, law enforcement, and public awareness has contributed to the alarming rise in road crash and casualties in Cambodia. Over the last five years, the number of road crashes has increased by 150% and the number of fatalities has almost double. The main cause of road crashes was from human error such as speeding, drunk-driving, and dangerous overtaking. Motorcycle riders are particularly vulnerable. Almost 77% of the total number of casualties and 68% of fatalities involved motorcycles. About 34% of those casualties are between the ages of 15-24. The lack of helmet wearing among motorcyclists is a major contributing factor to head injuries. Out of the 19,879 motorcycle casualties in 2008, 93% were not wearing helmets. As a result, head injuries accounted for 44% of total injuries.

The National Road Safety Committee (NRSC) of Cambodia, with the support of Asian Development Bank (ADB), developed Road Safety Action Plan, in which Raising Awareness of Road Safety and Enforcing the Road Traffic Law are two main components yet implemented by the government in particular aiming to promote helmet wearing among the motorcycle users. Seeing the gap, Handicap International Belgium (HIB) developed an integrated-campaign of Helmet Wearing Promotion and Enforcement in Cambodia. It was a good example tackling the situation while the government is still lack of resources for implementation.

In this paper, an attempt has been made to describe the experience of Helmet Wearing Promotion and Enforcement in Cambodia. Detailed description of the project including objectives, method, strategy, monitoring and evaluation technique, challenges and lessons learning from the project.
are also highlighted. At the very outset of the paper, a brief review of road safety problems particularly motorcycle crisis in Cambodia are also described.

1 BACKGROUND

1.1. Road Safety Overview in Cambodia

Given its relative stability and growth in recent years, Cambodia has seen a rapid increase in its volume of road traffic over the last three years. At the same time, weak traffic regulations, insufficient enforcement of the new road traffic law, improvement of the road network (allowing speed increases), lack of road safety education, and the inadequacy of public health infrastructures in providing treatment for traffic injuries have led to a rapidly rising number of road crashes and casualties.

In first semester of 2009, according to Road Crash and Victim Information System (RCVIS)\(^1\) - a report from traffic police and health combination showed that more than 4 persons die and at least 70 are injured daily on the roads of Cambodia. Indeed, the number of fatalities has been almost doubled within the last five years, 2004 to 2009.

Alarmingly, 54 % of casualties are among the active part of the population (age 15 to 29), with farmers and students the overwhelming majority. About 73% of all casualties and deaths are male (RCVIS 2008). Consequently, the groups most affected are invariably the main breadwinner in the household resulting in a loss of income for the family, high medical and/or funeral costs and in the case of injury rehabilitation costs.

1.2. The Motorcycle Crisis

Motorcycle riders are particularly vulnerable. Motorcycle crashes and casualties represent an alarmingly high percentage of overall crashes and casualties in Cambodia. Almost 77% of the total number of casualties and 68% of fatalities involved motorcycles. On the other hand, 34% of these casualties are between the ages of 15-24 years.

The lack of helmet wearing among motorcyclists is a major contributing factor to head injuries. As the World Heath Organization’s Helmet Report 2006 states, “motorcyclists who do not wear helmets are at a much higher risk of sustaining head injuries and from dying from the injuries”. In Cambodia, this statement is particularly true. Out of the 19,879 motorcycle casualties in 2008, 93% were not wearing helmets. As a result, head injuries accounted for 44% of total injuries.

With the tremendous growth of motorcycles in recent years – 40% increase from 2007-2008 alone – the situation is likely to worsen. Furthermore, surveys in 2007 show that only 21% of motorcycle riders in Phnom Penh and 16% of riders along the major national highways wear helmets (HIB 2006).

Attitudes towards helmets are also a contributing factor. Surveys in Phnom Penh show that the majority of young motorcycle riders who do not wear helmets state that the reason for this

\(^{1}\) Monthly report from January to June 2009, Road Crash and Victim Information System (RCVIS), Handicap International Belgium
behavior is they are not in the habit of wearing helmets, that helmets are too uncomfortable (ie. too hot) and the lack of punitive consequences to not wearing helmets. Moreover, a survey in June 2006 showed that 40% of those riders that wear helmets do not wear helmets properly. Therefore, there is an urgent need to promote helmet wearing and enforcement. Considering these facts, simultaneously with government initiatives, the Handicap International Belgium (HIB) developed an integrated-campaign of Helmet Wearing Promotion and Enforcement in Cambodia.

2. HELMET PROMOTION PROJECT OVERVIEW

2.1. Objectives
The objective of the project was to increase helmet wearing rates among targeted groups in Phnom Penh’s Makara 7 district.

2.2. Methods and strategy
Method
The method used in this project was based on practical experience gained from several years working in the field, together with some theories existing in other countries with adaptations to the context of Cambodia. Theoretically, amongst the 3Es, this paper is nonetheless focuses only on the Education and Enforcement combination while the Engineering is not involved. The first E- Education covers the awareness activities.

Stand-Alone Campaign versus Integrated Campaign
The experience showed that the past campaigns conducted by HIB were Stand-Alone Campaign that only helps raising awareness amongst target group. A change of behavior is very limited. For instance, in the past few years HIB, in collaboration with stakeholders, has developed several times of campaigns on various themes: Helmet Wearing, Over-loading, Speeding, and Drinking-and-driving. Much efforts, budget, were spent with some progress. Below is an example of the progress of helmet wearing rate amongst road users in Phnom Penh, where partly believed that the effect of the Stand-Alone Campaign in the past.

![Figure 1: Evolution of helmet wearing from 2004-Jun 2008](image)
Based on the helmet action plan of the government of Cambodia, HIB had been pushing government to implement the plan in a national level. Worthwhile, the date of enforcement on helmet was set by the Ministry of Interior (MoI). Right away, the strategy of Integrated Campaign was decided. The launching of the campaign was presented by several high representatives official from the NRSC, MoI, Ministry of Health (MoH), and some stakeholders. Noticeably, group of reporters from main TV, radio, newspapers, and magazines presented. The news was become one of the main topics during the time.

3. ACTIVITIES

3.1 Raised Awareness on the Importance of Helmet Wearing

- Development of awareness materials
  The promotion materials and message were designed and reviewed several times before final production following to the assessments results come from the targeted people. A group of volunteers went to the sites for conducting the assessments. Comments were taken into consideration with a development team.

- Awareness Campaign
  The awareness raising activities included a multi-media campaign, as well as community-based campaigns in Makara 7 District. A unique message was set “Protect your life, wear a helmet”. All promotion materials designed, and all activities were coordinated to make sure that they use exactly the same message. Both lasted two month, from November to December 2008, designed to be closely followed by the January 1\textsuperscript{st} 2009 helmet enforcement launch. There was an extensive integration of helmet message “Protect your life, wear a helmet” to existing TV and radio spot, and other materials. It was a common message that HIB asked TV and radio announcers to repeat announcing, when possible, to audience in several programs.

- Community-Based Campaign
  Eight public campaigns were organized in Makara 7 District (1 time/week) over the November and December. Road Safety Ambassadors (RSA) chose key locations within the district marked by heavy traffic flow for the campaigns. The RSA distributed road safety education materials, stressing the helmet wearing message. The ambassadors were youth selected from high schools and universities to help implementing the public education activities. Those students applied for the jobs after they had seen advertisement on information board at their university, or from friends. It was a completely volunteer work with little pay for meals and fuel only. Throughout the course of these campaigns, they became champions of road safety, promoting helmet wearing not only during the campaign activities, but in their daily life with friends and families at home and in their schools.

- Multimedia Campaign
  - TV Spots: Broadcasted a TV spot with the message “Protect your life. Wear a Helmet” on three popular national television channels. The airing times were only on prime time so that it could widely coverage to audiences.
  - Radio Spots: Broadcasted a radio spot with the message “Protect your life. Wear a Helmet” on three national radio stations. Same as TV airing, the radio broadcast
also on the main time only. The radio covers widely the country, as many parts of the country people could not afford or no electricity supply.

- **Posters:** Designed and developed the poster with the message “*Protect your life. Wear a helmet*” using international star Jackie Chan. The poster indicated clearly the date of enforcement on helmet wearing by traffic police. 1500 posters were distributed in key locations around the targeted district (roads, schools, markets, and other visible public places) by HIB’s road safety ambassadors.

- **Leaflets:** Developed the leaflet based on the poster, with additional tips on how to buy a good helmet were printed on the back of the leaflet. Road Safety Ambassadors distributed 40,000 leaflets to the identified targets group (market vendors, motor-taxi drivers, students) throughout the two-month campaign. The ambassadors disseminated verbal information on importance of helmet wearing to the recipients during distribution;

- **Display of banner with Tuk-Tuk (tri-cycle motor taxi) in Phnom Penh**
  Signed agreement with 51 Tuk-Tuk drivers to display, on the back of their vehicles, a board that specifically designed to promote the helmet wearing. As these tuk-tuks travel extensively around the city, the profile and visibility of the signs was very high. Every driver got one helmet for the displaying of the board in first month, and the follow months, get fee for it.

- **Announcers on TV and radio program**
  An encouragement amongst Master-of-Ceremonies in TV and radio programmers were contacted and suggested to announce when possible about the message of helmet wearing. Those announcers were provided one helmet for their show on stage, and introduce key messages they should appeal.
  The announcer also got some helmets for the actors who are on stage. During the discussion with those actors on platform, the announcers provide one helmet to any actor and announce the message “Protect your life, wear a helmet”. Most of TV and radio channels have showed good intention to do so. Boxing programs on TV were also included in this activity.

3.2 Helmet Subsidized and Distribution

- **2000 High School Students Accessed to Subsidized Helmet Distribution**
  All 2000 subsidized helmets were distributed from November-December 2008 to students at four selected high schools, where located in Makara 7 District, Phnom Penh.
  Several types of helmet were brought for a test amongst students at those schools on what type they want, before the order process starts. The test was to assure that they will wear the helmet after the distribution. The purchasing cost for each helmet was 10 dollars, but they were sold at the school for a subsidized cost of five dollars. Eight RSA, along with NRSC staff, were responsible for the helmet distribution at the schools. The scheme was conducted, in collaboration with school director, two times a day - one in the morning and afternoon. In total, 250 helmets were sold during each shift on a first-come-first served.

- **A Distribution of Helmet to Perspective Role Models**
  In addition, 500 helmets were distributed for free in two ways:
  1) 300 helmets were used as prizes during TV and radio media events such as concert, song contests, and sporting events.
2) 200 helmets were given to relevant government stakeholders (National Road Safety Committee staff, 7 Makara District officials, and school directors) to act as a role model while driving.

- **A Distribution of Helmet to Traffic Polices**
  Because traffic police would directly contact with the road users, HIB considered using them as a role model on helmet wearing. 1,890 helmets were provided to the Ministry of Interior and they would be distributed to traffic police through out the whole country. The ministry signed, on behalf of the traffic police, a commitment to use helmet all the time they ride on motorbike. The helmets were designed specially for traffic police to fit with the officially uniform requested by the Ministry of Interior.

3.3 Increase Skill of Traffic Police to Implement the Helmet Law
- **A Scoping Exercise**
A scoping exercise was conducted in April 2008 to assess the needs of the traffic police and the gaps in enforcement. The findings include:
  - Traffic police personnel receive basic training only in traffic control and the majority is learnt from experienced officers “on the job”. There is no specialized training in traffic policing on road safety;
  - Lack of understanding or exposure to contemporary road safety-based traffic law enforcement methodologies, no consistent operational procedures;
  - Traffic policing is under-resourced and ill-equipped;
  - Lack of commitment to enforcement, with public showing little regard for law and enforcement;
  - Underlying causes of road trauma in Cambodia are not acknowledged or understood by the traffic police.
Overall, as the scoping report recommends that a simplified professional development and training needs to be provided to traffic policing personnel focusing on both operations and road safety practice as a priority, along with the development of a national enforcement strategy, As a result of this scoping report, it was decided to integrate police training and strategy development into the helmet promotion project. The activities are included:

- **Leadership Workshop and Development of National Enforcement Strategy**
In anticipation of the helmet enforcement on January 1st, 2009t, HIB, in consultation with partner experience in police training, decided to integrate the ongoing Professional Development programme2 with this project. Two police experts were recruited to conduct the workshops.

The professional development programme added an additional element to the process – the development of a national enforcement strategy with a key priority on helmet wearing. The development of this strategy was a key output, and occurred during the leadership workshop that held 4 months before the enforcement starts and attended by 120 senior police officers from over 15 provinces. Through group discussions, input was collected on the key needs and priorities for traffic law enforcement in Cambodia, which was used to develop the strategy.

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- **Helmet Enforcement Training of Trainers (ToT) and Operational Training**

The helmet enforcement workshops were organized in advance of the anticipated helmet wearing law enforcement on January 1st, 2009. Helmet wearing enforcement was also a key strategic priority identified at the leadership workshop, and became a priority within the national enforcement strategic plan. This enforcement training, therefore, targeted the Phnom Penh Municipal traffic police as trainers, and the Makara 7 district traffic police as participants who were expected to operate the police checkpoints enforcing the helmet law.

a) **Helmet Enforcement Training of Trainers – one month before the enforcement starts**

The goal of the ToT was to enhance the trainer’s competencies and confidence to deliver the helmet wearing enforcement modules to all operational enforcement officers. There were 30 participants from the Ministry of Interior, Phnom Penh Police and various non-governmental organizations. They learned both theoretical modules and practical exercises including proper checkpoint enforcement. The workshop was facilitated by the same consultant conducting the professional development course.

b) **Helmet Enforcement Operational Training**

The goal of the training was to enhance the participants’ commitment to road safety and helmet wearing, and to improve their skills in safe checkpoint operations and helmet enforcement operations. There were 40 participants from the project’s target district – Makara 7. Five trainers were drawn from the ToT. Furthermore, the helmet wearing action plan was developed at this workshop. The ToT facilitator provided quality assurance and advice to the trainers during the operational course.

3.4 Helmet Wearing Enforcement in January 1st 2009

The enforcement of the helmet law at key locations in the targeted district (Makara 7) was launched by the Phnom Penh Traffic Police on January 1st 2009. It was the first time that the helmet law was enforced in Cambodia. Due to the enforcement actions of the police and the support provided by the project through awareness campaigns, police trainings and strategic development, the helmet wearing rate rose from 24% prior to the enforcement to 56% one month after the enforcement.

4. **MONITORING AND EVALUATION FRAMEWORK**

4.1 Project Preparation Phase

The project preparation phase began from January until February 2008. Key activities within that timeframe were to meet with the relevant national and municipal authorities to seek approval and outline the project objectives and actions. These meetings created the official framework for the implementation of the specific activities as the relevant authorities were committed to playing a role in the project, and understand what the project was trying to achieve.
4.2 Project Monitoring
Ongoing project monitoring was regularly provided by HIB through site visits, coordination meetings, and field observation. The media was also monitored to gauge the level of press the project awareness campaigns and enforcement was receiving.

For the helmet distribution at the four targeted schools, helmet monitoring forms were developed to gauge the level of helmet wearing among students who purchased helmets. Specific monitoring trips for the helmet enforcement were also conducted by the consultants responsible for the police training component of the project. Participant evaluations were also conducted during the helmet enforcement trainings to gauge the effectiveness of the course.

4.3 Project Evaluation
To assess the achievement of the project objectives, pre and post test survey were conducted by an independent research company – Solidus Asia, and using also the existing RCVIS report that record all road crash in Cambodia.

The pretest survey was conducted from June 21-30 2008, before the launch of the project activities and the post-test was conducted from 1-7 February 2009 following the enforcement of the helmet law by the traffic police.

A multi-stage sample selection method was adopted for both baseline surveys. Eight locations were selected and the survey was conducted during workdays and weekends in difference time covering the peak time and normal time (7:00-8:00am; 10am-11:00am; 15:00-16:00). The sample size designed for the survey was 720 that cover all type of road users (student 400, street vendors 60, motor-taxi drivers 100, housewife 100, and government employees 60).

Two types of surveys were conducted:
- Traffic Audit on Motorcycle Helmets: used to count the number of correct helmet wearing among drivers and passengers. The survey conducted 3 times/day from Monday through Sunday;
- Qualitative survey: used to gauge the level of change among motorcycle users on attitudes and behaviors towards helmet use and laws. 204 respondents were selected as the sample size from the identified target group of students, motor-taxi drivers and market vendors.

For the police enforcement actions, a scoping exercise and a quality assurance report post-enforcement were commissioned from the police consultants. Furthermore, individual workshop participant evaluations were conducted during all trainings.

5. PROJECT ARCHIEVEMENTS
The results from the pre and post test surveys clearly shows that the project objective was achieved while the helmet wearing rate amongst motorcycle driver doubled from June 2008 (before the awareness campaigns and helmet enforcement) to February 2009 (one month after the enforcement) from 24% to 56%. Passenger helmet wearing rates also nearly doubled over the same time period from 6% to 11% (Figure 2).
The most recent Road Crash and Victim Information System (RCVIS) points to slight decrease in head trauma cases in Phnom Penh and the rest of the country from December 2008 (before the law was enforced) to March 2009, when the project end (Figure 3). Another proxy indicator has been the increase of helmet wearing noticed on road traffic crash victims.

The results from the commissioned survey clearly show the change of awareness and attitudes towards helmet wearing amongst road users in 7 Makara District. Some sample results are presented below from the pre and post test.

Prior to the campaign, the popular belief was that wearing a helmet was to either protect them from dust, wind or rain 80%. Protection of the head 62% and the prevention of risks from accidents 33% were only secondary concerns.

After the campaign, the top responses were that helmets protect the head and protect their life. Another significant increase was the response (figure 4) that helmets prevent serious injury risk when involved in an accident (up from 1% to 24%).
Prior to the campaign, the correctness rate of those who wear a helmet was increased in all surveyed locations (figure 5).

6. CHALLENGES AND LESSONS LEARNED

The helmet wearing promotion project presented a few challenges and lessons learned as outlined below:

6.1. Challenges

- One of the project strategies was to use government staff (from the police and national road safety committee) as project officers to build their capacity in project implementation. However, they were not able to devote enough time to project duties;
• There are many obstacles within the collaboration amongst local authorities, most notably the time needed to negotiate through the government’s bureaucratic processes. Activities were delayed several times because of this challenge;
• The project timeframe was short. According to the independent survey, the awareness component of the project could have benefited from a longer timeframe, providing a greater chance that the target groups and public benefit from the messages of helmet wearing and enforcement;
• There is no passenger helmet law in the traffic law. All these factors together lead to a general unwillingness to wear helmets;
• Traffic police did not continuously enforce the helmet law after January 1st. As a consequence, while the helmet wearing is not become a habit, and the wearing rate might decreased.

6.2. Lessons Learned
The project, over the course of this pilot phase, generated the following lessons learned:
• For the first time, helmet wearing education and awareness campaigns were linked to enforcement. This approach was effective as the public were ready for the enforcement date as evidenced by several articles in the media about the importance of wearing helmets leading up to enforcement, and shops selling helmets increased and reported a brisk business;
• It is important to have a clear and unique message during the campaign. The message in this campaign was “Protect your life, Wear a helmet”. According to the independent survey, the majority of the respondents remembered this message;
• Collaboration and coordination amongst stakeholders is a key to success because all partners were able to share resources and technical expertise, as well as avoid duplication of activities, throughout the project duration;
• Subsidized helmet distribution is a successful model for giving access to helmets to a wide-range of people (students, teachers, civil servants). There was tremendous interest in this activity so much so that the demand far outstripped the supply. This scheme should be replicated in future helmet promotion projects;
• The helmet enforcement training broadened and improved the knowledge and skills of the traffic police. The traffic police combined these new techniques with their traditional enforcement model at the checkpoints during helmet law enforcement.

7. CONCLUSIONS
The project was successful in achieving its objective by changing the attitudes and behaviors of motorcycle users in Phnom Penh by raising the helmet wearing rate from 24% before enforcement to 56% post-enforcement, as well as shifting the belief of motorcycle drivers that helmets are an important safety feature when driving.

This achievement was largely due to the effective implementation of helmet promotion activities including awareness campaigns, subsidized helmet distributions, enforcement trainings. In addition, a key element of the project was a combined strategy that links education with enforcement, which helped to raise the profile of the campaign with the public and within the
media, as well as providing the police trainings with immediate relevancy, thus increasing the commitment and motivation of the participants.

The project was also able to bring a variety of partners together towards a common goal of improving helmet wearing in Phnom Penh including the National Road Safety Committee, the Phnom Penh municipality, the Ministry of Interior and traffic police, as well as partner organizations active in road safety. The focused of the efforts in a coordinated way on a single message and result, and therefore the commitment from all partners became a key strength of the intervention.

The feedback from all beneficiaries and stakeholders was positive. This project was a pilot phase and the model proved effective. There is tremendous need to scale-up these helmet activities throughout Phnom Penh and in the provinces. Therefore, it is recommended that the helmet promotion projects are replicated in urban and rural areas to ensure that the widespread high-risk behavior of non-helmet wearing is tackle to reduce head trauma in Cambodia.

REFERENCES
Handicap International Belgium (2009) Road Crash and Victim Information System (RCVIS), Monthly report from January to June 2009.
How to promote traffic safety among youth?: A multiple-approach plan from Luchemos por la Vida.

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By Lic. María Cristina Isoba, Director of Road Safety Education and Research, Luchemos por la Vida. Argentina

Abstract

The World Health Organization estimates that “every day just over 1000 young people under the age of 25 years are killed in road traffic crashes around the world. It became one of the most important issues in Traffic Safety.

The objective of this presentation is to share some experiences and approaches to traffic safety education for children and teenagers through different programs such as "Schools for life", "Workshop: Young people for life", preparation of Specific Teaching Materials and other activities developed by a non governmental, non-profit organization called “Luchemos por la Vida” ("Let's fight for life"), that works to prevent traffic accidents in Argentina, a developing country with 39 million inhabitants, where 22 people are killed each day (more than 8,000 a year)*, another 130,000 are injured each year, and dramatic material losses (estimated in USS 10 billion a year)** result from traffic collisions. In this country, 2,269 children and teenagers between 13 to 25 years old died last year in traffic.

Since what we know about traffic safety education, scope and limits, considering that the main objective of traffic safety education must be to make students aware of the fact that they are an active and responsible part of the traffic system, and taking into account that young people are influenced by factors such as emotional instability, rebelliousness, influentiability and omnipotence that condition their attitudes and behaviors; we want to discuss an important topic: what’s the best moment to start with traffic safety education and the most effective tools to achieve safe young drivers.

How to promote traffic safety among youth?: A multiple-approach plan from Luchemos por la Vida.

by Lic. María Cristina Isoba

The purpose of this presentation is to share some experiences and approaches to traffic safety education for children and teenagers developed by Luchemos por la Vida ("Fighting for Life"), a non governmental, non-profit organization, that works to prevent traffic accidents in Argentina, a developing country with 39 million inhabitants, where 22 people are killed each day (more than
What We Know About Youth in Traffic

World Health Organization estimates that “every day just over 1000 young people under the age of 25 years are killed in road traffic crashes around the world. Road traffic injuries are the leading cause of death globally among 15 to 19-year-olds, and the second for ages from 10 to 14-years and 20 to 24-years. (1). In our country, Argentina, 2,269 children and teenagers between 13 to 25 years old died last year in traffic. "The excessive participation of young, male users in accidents is one of the most frequently observed phenomena in traffic all over the world. It is so common that it feels like a law of nature. Its magnitude suggests that (this phenomenon) must involve much more that mere lack of experience”, says American researcher Leonard Evans (1999). In fact, in the analysis of possible causes, specialists agree on the importance of the evolutionary stage where youth under 25 years of age are. It is said that the fatal mix is a combination of immaturity and inexperience. Youth are influenced by factors such as emotional instability, rebelliousness, influentiability and omnipotence that condition their attitudes and behaviors. They make mistakes when driving, they drive at high speeds, they are easily distracted (especially when driving with their peers) and also as pedestrians, they usually place themselves in limit situations.

What we know about traffic safety education: traffic safety definition, scope and limits

Historically, in most countries, traffic safety education was part of the first efforts to increase traffic safety. In this way, the objective was to pass on information about the rules in force. Studies and evaluations of different educational experiences internationally have proved that traffic safety education based on the mere passing on of technical information does not produce changes in attitudes or behaviors. Equally ineffective are the results of drivers’ training courses taught in high school; because they contribute to earlier licensure for young drivers, these programs usually increase motor vehicle fatality rates for young persons (Vernick, 1999). Courses that teach some driving skills, when taught to young men, the outcome was adverse. Males trained in these skills became overconfident in their ability and now take unnecessary risks, says Dan Mayhew from Canada.

“The belief that the knowledge in and of itself will change the behavior of drivers and other road users is a naïve vision of the human behavior”, says Allan Williams (2007), Insurance Highway Institute chief scientist.

Then, you might think, all traffic safety education efforts might as well be dropped, since it is not effective in itself. Yes, it is true; traffic safety education as a mere passing on of information about traffic safety signs and rules should be dropped. That does not work. But, of course, that is not what traffic safety education really is, in a wide sense.
Road safety education is much more than teaching about rules and traffic signs. Much more than just passing on information. Moving on roadways is a process that involves the whole person, in their psycho-physical individual aspects and the way they relate to other people and the environment.

- Considering this, the main objective of traffic safety education must be to make students aware of the fact that they are an active and responsible part of the traffic system.

We, at Luchemos por la Vida, promote traffic safety education in a wider sense, together with more effective law enforcement (Education + Enforcement), a combination that has proved being most effective in changing towards safer behaviors in traffic.

**How to Work With Youth**

In fact, traffic safety education, in a wide sense, starts practically, through the parents’ example to their children as they start walking with them when they are very little. That is why, most of the times, children learn wrong behaviors directly from their parents. Therefore, to have safer youth in traffic, we need to work with adults, so that they become safe adult drivers that can be a model or an example of safe behavior in traffic. They must also warn their children about the risks that they face when they are little children and later, as young persons; to protect them when they are little and to guide them and supervise them when, as young persons, they start to drive.

And we must work with young people before they get to that age; when they are still children, so that they understand and internalize, just as adults must do, two basic elements: traffic as a system that they create in interdependence with others, and the concept of risks in traffic, learning to distinguish risky behaviors from those that are not, both in theory and in fact. It is essential to provide them at the ages of 11 to 13, when they evolve in their intellectual development from the stage of concrete operations to the ability of abstract thought that allows them to establish associations and relations that facilitate a wider understanding and perception of risk. Besides, they are in an age where there is still a greater openness to the adult figure and authority, with a lesser influence of the peer group.

Working with adults and children will contribute to making a generation of youth with greater risk awareness.

**How does Luchemos por la Vida promote traffic safety among youth?**

We decided to develop a multiple-approach plan aimed at the individual “in the community” to generate a social change of attitude towards traffic accidents and behavior on the streets, and a better awareness about traffic “as a system” in order to provoke changes in the system of individual beliefs and attitudes. To do this, we decided work among: mass media, government and traffic safety education.
Mass awareness campaigns, by means of advertising spots on radio and TV. Since 1992, through some free time mainly from voluntary donation of radio and TV companies, our association carried out the only campaign that has been on the air for more than seventeen years now, designed to prevent more road accidents, aiming continuously to make people aware of the serious problem of traffic accidents, in order to increase the “perception of risk” among road users and provide concrete information on safe behaviors connected with the main factors causing accidents and mortality in traffic (speeding, drinking and driving, night driving, use of seat belts, helmets, etc.).

Some of these campaigns are specially focused on children and youth issues.

Let us watch one of the first campaigns (1994) created by the Association, dealing with pedestrian safety. (RAP Campaign)

This spot had a high impact on the community and the follow up to the campaign showed a slight increase in safe behaviors of pedestrians and a greater impact on pedestrian priority.

Another example of awareness campaigns aimed at youth was this one: “Safe Summer” (2009) (Summer Campaign).

Finally, we can watch the campaign that is currently being aired, geared towards the youth segment, to encourage helmet use (Helmet Campaign), that, starting with the most common conceptions and reasonings about not wearing a helmet, aimed at a cognitive restructuring with the provision of related information.

The question that arises is: Have these campaigns been effective? After different kinds of follow up through surveys and systematic follow up observations, we can say that they have, but with limits. Because:

-The message was received.

-The message was understood.

-Changes of behavior occurred in relation to the subject.

But, as it happens all over the world, campaigns have certain limits, since, as it is known, education only is not enough. Campaigns are indispensable, but not sufficient to change the conduct of the majority. Other things are need as well:

-Effective controls
-Effective punishment

In our experience, we agree with Peter Vulcan: “Advertising is very effective only when accompanied by high levels of controls and punishment”. However, in and of themselves, they are also a very helpful tool for the population in general and for youth in particular.
Trafic Safety Education in Schools

“Schools for Life” and “Young People for Life” Programs

From its beginning in 1990, “Luchemos por la Vida”, has been investigating and working intensely in the area of Traffic Safety Education in schools. We developed a systematic concept of traffic: this educational approach has been successfully applied in Argentina for fourteen years now, with more than 150,000 children and teenagers ages 6-18, and has been promoted among teachers and public officials.

OBJECTIVES: To develop in children and youth a preventive awareness of traffic accidents, to motivate and to start new attitudes, behaviors and habits, responsible and solidary, for the preservation of life on public roads.

Let us see one of the activities that take place inside the classroom, aimed at children ages 11-13, called “The Street Game”. (Ver juego de la calle. Mientras tanto explicar: With this simple “game” in the classroom, they experienced and felt, physically and emotionally, what “making” traffic and inter-dependency are, and almost simultaneously, they discovered why traffic rules exist. Through the “chaos” of a simulated situation, they discovered and recognized the value of “order”).

Now they can come out on the street from school and start to “think” and “make” traffic with a different mind.

METHODOLOGY: Starting from a pedagogic “constructivist” approach, objectives are planned to be met through participatory activities, in the form of “workshops” where the students are the true protagonists of the action. With group techniques, starting from their experiences and beliefs.

Preparation of Specific Teaching Materials

Our most recent production is the DVD film: “Pedestrian Hunters”. This new teaching material developed by our Association is offered at no cost to public and private elementary schools that request it.

The film promotes student participation and stimulates their ability to reflect on the subject of traffic system and safe pedestrian behaviors. Using a funny and exciting story that has a group of children as the main characters, it shows the most common risky behaviors of children and adult pedestrians, in order to encourage the audience to reflect on what they are watching. The film must be completed by students who have to discuss and think about the safe pedestrian’s behaviors. A guide for classroom activities is provided with this film.

Other initiatives
Different initiatives such as gradual granting of driving licenses, that limit the mobility of young drivers in their first stages, avoiding riskier situations such as night driving, driving with peers, etc.; the involvement of parents accompanying and monitoring the first stages of driving; BAC tests in areas where young people often “hang out” at night; and encouraging the “designated driver” approach, are some of the tools that our Association promotes.

Conclusion

Undoubtedly, the traffic system poses risks for the human being, who is changing and vulnerable, especially when young.

As we have said before: Even though we know that “technology, infrastructure, legislation and enforcement must be subservient to adequate behavior (Huguenin, 2005), according to the acceptance that the human error is impossible to be totally eradicated in traffic”, we think the time of educational and awareness intervention is not over. Especially in developing countries that have huge problems to implement an effective enforcement of the law.

Developing countries need to build up, as the World Health Organization says, “a new traffic safety vision with a more interdisciplinary and integrative approach, thorough intersectorial collaboration, targeted policies and national action plans”. And non governmental organizations, as Luchemos por la Vida, can make valuable contributions in this field.

REFERENCES

- Isoba, María Cristina “Sólo con educación no se hacen conductores más seguros” "Luchemos por la vida" magazine - Año 6 - Nº 19. Buenos Aires, Argentina.
Contents session 12  Safety management techniques including speed management

Speed and Safety: Evidence from Highways in China
Xiaoduan Sun, University of Louisiana, USA

Differentiated Rural Speed Limits – can this be done Safe?
Jesper Mertner, COWI A/S, Denmark

A practical Traffic Safety Activity by Utilizing Identified Hazardous Map Development to Raise Road Safety Awareness in Thai Community
Tuenjai Fukuda, Research Institute of Science and Technology, Nihon University, Japan

Implementing Traffic Safety Community-Based Activity for Development of Traffic Safety Culture in Vietnam
Tuenjai Fukuda, Research Institute of Science and Technology, Nihon University, Japan

Quantitative Assessment of Used Tires Impact on Road Safety in Developing Countries
Mr. Godfrey Lamptey, P.E., Corzo Castella Carballo Thompson Salman (C3TS), USA
ABSTRACT
The relationship between speed and traffic crashes has been a subject of research interest for many years due to its significance in efficiency and safety of highway operations. The complex and sometimes inconsistent results of these studies come from the diversity of highway design, traffic characteristics and most importantly driver behaviors. This paper presents the results of a project that investigates how operating speed affects highway safety in China. Particularly, this study developed a model to explore the relationship between speed and safety.

As highway mileage in China expands quickly with unprecedented investment in roadway construction, safety and efficiency have become top priority. The results of this study indicate not only operating speed but also the magnitude of speed differential between large and small vehicles significantly affects crash occurrences. The results provide much needed information on how to manage speed in order to maximize both safety and traffic flow efficiency in a practical manner.

Key words: Speed, highway safety, safety model

1 INTRODUCTION
As highway mileage in China expands quickly with unprecedented investment in roadway construction, highway safety and efficiency have become the top priority in the field of highway transportation. The annual number of crashes has been increased exponentially based on the officially published record. It is widely suspected by both traveling public and engineering professionals in China that speed is closely related to highway safety. In 2005, 11.69 percent of total crashes were speed-related, which means that speeding killed approximately 16,000 Chinese. The speed-related crashes also injured more than 53,000 and cost 25,183 million Yuan. Overall, speed-related crashes represent 16.22%, 11.28% and 13.37% share of the casualties, injuries and economic cost of the total crashes as reported by Wang. According to a study report conducted by Sun, speeding accounted for 22.12 percent of casualties on Jingjintang Expressway, one of the first freeways built in China.
2 REVIEW
Exploring the relationship between speed and highway safety has been a popular research topic for many years. Particularly, a high volume of studies has been published after the repeal of the National Maximum Speed Limit (NMSL) in the U.S.

Some of the U.S. studies conclude that the initial 55 mph speed limit coming into effect in 1974, contributed to the mitigation of roadway crashes. After analyzing the crash data from 1971 to 1975, Labrum suggested that the imposition of the 55 mph speed limit and other factors caused a noticeable reduction in fatalities on roads. Using the interrupted time series analysis, Meier and Morgan concluded that the 55 mph speed limit caused the decline in roadway fatalities from 1973 to 1974. Burritt found that among all the facilities where the 55 mph speed limit was imposed, interstate highways that had previous speed limit of 75 mph experienced the largest decrease in total accident rates. A few other factors that might also have an impact on crashes were also investigated, including driver characteristics, vehicle characteristics, traffic-related environmental factors and travel patterns. The Burritt study eventually showed that neither driver nor vehicle characteristics made a difference in the reduction in fatalities in 1974. A research conducted by Dart investigated the role of police enforcement on traffic speeds and crashes in North Carolina, Mississippi and Louisiana during the same time period and found that the initial decline in traffic speeds had been eroded and operating speed had returned to the pre-NMSL level. However, the standard deviations were lower after the 55 mph speed limit came into effect, which, author believes, must be attributed to the increased enforcement levels from 1974 to 1976. The same study also observed a large reduction in fatalities on rural highways and a significant decline in the total rural accidents.

The repeal of NMSL was generally thought of as being followed by an increase in roadway crashes and fatalities. Farmer et al. found that fatality rates were higher following the repeal after accounting for changes in vehicle miles traveled on interstates while deaths on non-interstates were essentially unchanged. By using different methodologies, both Haselton et al. and Hauer’s studies detected a marginally significant increase in total crash counts and fatality crash rates after the speed limit was readjusted from 65 mph to 70 mph.

Although speeding has been considered as a serious problem in highway safety in China, few studies have derived the reliable conclusions regarding the magnitude of the impact due to lack of reliable data. This paper investigates speed impact on highway safety by developing a quantitative model linking crashes to vehicle speed through a safety performance model.

3 DATA
The study required three types of data; speed, roadway geometrics, and accident account.

3.1 Speed Data
The speed data were collected from six freeway segments and three first-class rural highways. The first-class highway in China is defined as the high speed highways with multiple lanes. The topography of the selected highways varies greatly from the Middle Plain of China to the mountainous areas in the South and southwester region. Table 1 lists the summary of the selected highways.
<table>
<thead>
<tr>
<th>Highway Location (Province)</th>
<th>Highway Class</th>
<th>Speed Limit (km/h)</th>
<th>Number of Data Collection Sites</th>
<th>Other Relevant Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luo-Fu (Yunnan) Freeway</td>
<td></td>
<td>Large Vehicle: 80</td>
<td>21</td>
<td>12 sites in tunnel; 9 on down slope.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Vechile: 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>An-Xin (He’nan) Freeway</td>
<td></td>
<td>Bus:100</td>
<td>2</td>
<td>Tangent 24-hour data collection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large Truck: 90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Vehicle: 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yu-Yi (Chongqing) Freeway</td>
<td></td>
<td>80</td>
<td>1</td>
<td>Lots of Speeding vehicles 24-hour data collection</td>
</tr>
<tr>
<td>Yu-Qian (Chongqing) Freeway</td>
<td></td>
<td>100</td>
<td>3</td>
<td>Challenging geometrics with horizontal-vertical curve combination and long segment in downhill.</td>
</tr>
<tr>
<td>Yu-Sui (Chongqing) Freeway</td>
<td></td>
<td>Large Vechile: 80</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Vechile: 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yu-Lin (Chongqing) Freeway</td>
<td></td>
<td>100</td>
<td>1</td>
<td>24-hour data collection</td>
</tr>
<tr>
<td>Lian-Huo (Xinjiang) 1st- Class Rural Highway</td>
<td>Large Vehicle: 80</td>
<td>16</td>
<td>7 sites on horizontal-vertical curve combination</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small Vechile: 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lou-Lian (Hu’nan) 1st- Class Rural Highway</td>
<td>80, 40</td>
<td>6</td>
<td>24-hour observation.</td>
<td></td>
</tr>
<tr>
<td>Tan-Shao (Hu’nan) 1st- Class Rural Highway</td>
<td>80, 40</td>
<td>6</td>
<td>24-hour observation.</td>
<td></td>
</tr>
</tbody>
</table>

Large vehicle in China is defined by vehicle with axis distance larger than 3.8 meters (12.46 feet). Vehicles with axis gap smaller than 3,8 meter is defined as small vehicle. The duration of the speed data collection varies depending on the site characteristics.

3.2 Highway Design Attributes
Gathering the highway geometric design information for all speed data collection sites is not an easy task. Ideally, original design blueprints are the best source for the data. However, the research team only managed to get one freeway design file for all geometric feathers at each site. The rest of highway layout information such as horizontal curve radius, grade, and curve length were manually surveyed on each site with the instruments.
3.3 Crash Data

Similar to the most of developed countries, obtaining accurate and reliable crash data is a big challenge in highway safety study. It is easy to have aggregated crash statistics but very hard to have all individual crash reports needed for the study. By visiting the local highway policy units along the data collection highways and sometimes helping the policy units to digitalize the historical crash records, the research team was able to collecting crash records for the sites used in this study. The summary of crash data is listed in Table 2.

### Table 2: Crash Data Summary

<table>
<thead>
<tr>
<th>Highway</th>
<th>Highway Class</th>
<th>Time Period Crash Data Collected</th>
<th>Total Crashes</th>
<th>Fatalities</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luo-Fu</td>
<td>Freeway</td>
<td>2007/10~2008/6</td>
<td>235</td>
<td>45</td>
<td>66</td>
</tr>
<tr>
<td>Lian-Huo</td>
<td>1st-Class Rural Highway</td>
<td>2004/1~2008/4</td>
<td>474</td>
<td>102</td>
<td>189</td>
</tr>
<tr>
<td>Yu-Yi</td>
<td>Freeway</td>
<td>2002/1~2005/12</td>
<td>539</td>
<td>144</td>
<td>651</td>
</tr>
<tr>
<td>Yu-Qian</td>
<td>Freeway</td>
<td>2001/10~2005/11</td>
<td>303</td>
<td>74</td>
<td>236</td>
</tr>
<tr>
<td>Tan-Shao</td>
<td>1st-Class Rural Highway</td>
<td>2004/10~2008/10</td>
<td>57</td>
<td>24</td>
<td>56</td>
</tr>
<tr>
<td>Lou-Lian</td>
<td>1st-Class Rural Highway</td>
<td>2004/10~2008/11</td>
<td>115</td>
<td>57</td>
<td>265</td>
</tr>
</tbody>
</table>

The crash statistics in Table 2 indicate a very high proportion of fatalities and injuries, which is quite unique in countries that were formerly less motorized, but are currently in a rapid motorization stage. The fatalities per crash vary from 0.19 to 0.5, and the maximum injuries per crash are 2.3 at the 1st-class highway in Tan-Shao. Two factors contribute to this extremely high percentage of fatality and injury: the practice in crash recording and high occupancy vehicles. In China, minor crashes – crashes with no personal injuries - are less likely to be reported.

4 METHODOLOGY

To reveal the relationship between safety and a host of factors in highway design and traffic operation, an analytical model was developed in this study by treating the expected crashes per time unit as the dependent variable. The independent variables include speeds and important highway geometric feathers.

4.1 Crash Prediction Model

Although the massive data were collected from many highways with different design and operation characteristics, the number of roadway sections used in this study is
only 86. Many roadway sections do not have a complete database in either crash or highway design. Missing reliable data presents one of the biggest problems in highway safety research in developed countries.

The segments used in this model development are homogeneous highway segment. Within each segment, the main highway attributes and operating characteristics remain the same. There are 36 segments on horizontal curves. The summary of the traffic operation characteristics is listed in Table 3 and summetry of the highway geometric feathers is listed in Table 4.

**Table 3: Summary of the Traffic Operation Attributes**

<table>
<thead>
<tr>
<th>Traffic Volume (veh./h)</th>
<th>Large Vehicle (%)</th>
<th>Large Vehicle Mean Speed (km/h)</th>
<th>Small Vehicle Mean Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>374</td>
<td>67</td>
<td>90.0</td>
</tr>
<tr>
<td>Minimum</td>
<td>47</td>
<td>11</td>
<td>38.3</td>
</tr>
<tr>
<td>Average</td>
<td>75</td>
<td>21</td>
<td>48.0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>45</td>
<td>13</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**Table 4: Summary of the Highway Geometric Feathers**

<table>
<thead>
<tr>
<th>Segment Length (km)</th>
<th>Grade (%)</th>
<th>Length of Slope (km)</th>
<th>Radius (m)</th>
<th>Yearly Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>2.650</td>
<td>6.0</td>
<td>2.65</td>
<td>3000</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.083</td>
<td>-3.6</td>
<td>0.08</td>
<td>600</td>
</tr>
<tr>
<td>Average</td>
<td>0.541</td>
<td>2.89</td>
<td>0.52</td>
<td>1905</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.371</td>
<td>2.0</td>
<td>0.36</td>
<td>914</td>
</tr>
</tbody>
</table>

1. Positive number for upgrade and negative for down grade
2. Excluding tangent segments

A generalized linear model is used in this study as shown in Equation 1. When traffic exposure (traffic volume) or segment length reaches zero, the predicted crashes is zero. The model’s exponential component can be converted to a linear form by log transformation, which makes the multiplicative pattern to an additive format.

\[
E(n) = a_0 \times L^{a_1} \times \text{Expo}^{a_2} \times e^{\sum_{j=1}^{n} b_j x_j}
\]

**(1)**

Where,

- \( E(n) \) – expected number of crashes;
- \( L \) – segment length (km);
- \( \text{Expo} \) – exposure in traffic volume;
- \( x_j \) – explanatory variable;
- \( a_j \) – regression coefficients
After log transformation, the model becomes:

\[
\ln[E(n)] = \ln a_0 + a_1 \ln(L) + a_2 \ln(\text{Expo}) + b_1 \cdot LV + b_2 \cdot \text{diff} + b_3 \cdot u_{sv} + b_4 \cdot g + b_5 \cdot \text{curvature} + b_6 \cdot \text{type}
\]

Where,

- \( LV \) - percentage of large vehicle;
- \( \text{diff} \) - difference in average speed between two types of vehicles;
- \( u_{sv} \) - average operating speed of small vehicles (km/h);
- \( g \) - grade of vertical slope (%);
- \( \text{curvature} \) - inverse of weighted radius for a given segment;
- \( \text{type} \) - binary variable for roadway class, 0 for freeway and one for 1st-class rural highway;
- \( b_j \) - coefficients

Instead of using speed of big and small vehicles, the difference in the operating speed between two types of vehicles is used as a variable in the initial model. A previous study published by Chen has indicated that the biggest negative impact on safety and traffic operation is from the differential speed. The estimated coefficients of the model is given in Table 5.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DF</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>95% Confidence Limits</th>
<th>Chi-Square</th>
<th>Pr&gt;ChiSq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>-17.97</td>
<td>5.59</td>
<td>-28.95 -7.00</td>
<td>10.31</td>
<td>0.0013</td>
</tr>
<tr>
<td>( \ln(L) )</td>
<td>1</td>
<td>1.84</td>
<td>0.34</td>
<td>1.15 2.52</td>
<td>27.75</td>
<td>0.0001</td>
</tr>
<tr>
<td>( \ln(\text{expo}) )</td>
<td>1</td>
<td>4.06</td>
<td>1.07</td>
<td>1.94 6.17</td>
<td>14.20</td>
<td>0.0002</td>
</tr>
<tr>
<td>( LV )</td>
<td>1</td>
<td>16.76</td>
<td>4.90</td>
<td>7.16 26.37</td>
<td>11.70</td>
<td>0.0006</td>
</tr>
<tr>
<td>( \text{diff} )</td>
<td>1</td>
<td>0.10</td>
<td>0.03</td>
<td>0.03 0.16</td>
<td>9.81</td>
<td>0.0017</td>
</tr>
<tr>
<td>( u_{sv} )</td>
<td>1</td>
<td>-0.08</td>
<td>0.03</td>
<td>-0.14 -0.02</td>
<td>6.93</td>
<td>0.0085</td>
</tr>
<tr>
<td>( g )</td>
<td>1</td>
<td>-0.12</td>
<td>0.09</td>
<td>-0.31 0.07</td>
<td>1.43</td>
<td>0.2325</td>
</tr>
<tr>
<td>( \text{curvature} )</td>
<td>1</td>
<td>607.87</td>
<td>203.56</td>
<td>208.89 1006.841</td>
<td>8.92</td>
<td>0.0028</td>
</tr>
<tr>
<td>( \text{type} )</td>
<td>1</td>
<td>-4.77</td>
<td>2.02</td>
<td>-8.74 -0.80</td>
<td>5.55</td>
<td>0.0184</td>
</tr>
<tr>
<td>Scale</td>
<td>0</td>
<td>0.52</td>
<td>0.00</td>
<td>0.52 0.52</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As expected, the segment length, traffic volume, percentage of large vehicle, speed difference between two types of vehicles and curvature are positively correlated to the expected crash counts. The magnitude of these variables increases, the expected crashes increases. The negative coefficient for grade indicates the down slope highway segment is more dangerous than the segment in uphill, which is consistent from the stories the research team heard over and over while taking to the local enforcement agencies that out-of-control overloaded trucks on downhill pose the biggest threat on the highway safety. The negative coefficients for the speed of small vehicle surprised us initially. When replacing \( \text{diff} \) variable with operating speed of large variable, the coefficient for speed of small vehicle changes from the negative (-0.08) to the positive 0.0243. At same time, the coefficients for the large vehicle is
negative 0.1045, which can be easily explained that the higher average operating speed of small vehicles, the higher number of crashes, and the higher average operating speed of large vehicles, the fewer crashes. The opposite sign of coefficients for small and large vehicles reveals indirectly the impact of differential speed on crashes. Taking both cases into consideration, the final model is shown below:

\[
E(n) = 1.55797 \times 10^{0.08} \times L^{1.8421} \times \text{Exposure}^{4.0628} \times e^{b_j x_j}
\]  

Where:

\[
b_j x_j = 16.77LV + 0.1 \text{diff} - 0.08u_{sv} - 0.12g + 607.87R
\]  

\[
b_j x_j = 16.77LV + 0.024u_{sv} - 0.105u_{LV} - 0.12g + 607.87R
\]

Equation 3a is for using variables of differential speed and average speed of small vehicles and 3b for small and large vehicles' speeds.

### 4.2 Crash Distribution Model

The safety prediction model such as the one developed in previous section calculates the expected number of crashes per a time unit. Considering the seasonal variation, the common time unit is usually one year or multiple years. Because of stochastic nature of crash occurrences, actually observed annual crashes of a highway facility (segment or intersection) will be fluctuated around the expected value. Poisson distribution model is commonly used in predicting probability of crash occurrences as shown in Equation 4.

\[
P(n) = \frac{\lambda^n \cdot e^{-\lambda}}{n!} \]  

\[
E(n) = \lambda
\]

\[
Var(n) = \lambda
\]

*Where,*

- \(Y\) - yearly crash counts;
- \(\lambda\) - mean of the distribution

The Poisson distribution assumes that the mean equals the variance, which is sometimes contradicted by the over-dispersion phenomenon, where the observed variance is larger than the mean. To tackle this problem, a parameter, called the dispersion parameter, can be introduced to the model, to lower the impact of over-dispersion on parameter estimations, which is called over dispersed Poisson distribution. In addition to the dispersion parameter, Negative Binomial (NB) regression can also be applied to data which exhibit over-dispersion trait. NB and Poisson are linked by different specification of their mean. The mean of the Poisson distribution is a constant while that of the NB is treated as a statistics following a Gamma distribution.
6 DISCUSSION
By including the speed in highway safety prediction model, the results from this study have shown that there is a clear relationship between speed and safety. Most importantly, the study has quantitatively revealed the significance of speed differentials. The bigger speed gap between two types of vehicles, the more crashes on a highway. Another important variable identified by this study in highway safety is traffic composition in terms of the proportion of large trucks. Truck traffic increases, the number of crashes increase.

REFERENCES
DIFFERENTIATED RURAL SPEED LIMITS - CAN THIS BE DONE SAFELY?

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ABSTRACT
The paper presents the methodology and findings of a project carried out by the Danish Road Directorate and COWI aimed at identifying sections where the speed limit could be increased from 80 km/h to 90 km/h without jeopardising road safety, requiring only minor and inexpensive measures. The paper describes how to systematically assess the rural road network when the speed limit is to be increased.

The project identified a number of road sections which were appropriate for higher speed limits. A number of measures were identified which must be taken into consideration to ensure that the sections are as safe as before the speed limit was increased, together with the associated costs. Finally the consequences of the changed speed limits were assessed. The project identified stretches of road which have the potential for higher speed limits. However, there are certain costs of implementing measures to avoid the reduction of road safety.

1. INTRODUCTION AND BACKGROUND
In Denmark, it is being considered whether to apply differentiated speed limits, allowing higher speeds on certain road sections, while maintaining safety standards. Typically, higher speed limits will increase the number of accidents, and the project must therefore prove that it is possible to maintain road safety while increasing speeds.

1.1 Background
In Denmark the general speed limit is 80 km/h (for trucks and cars with trailers 70 km/h) on non-urban and non-motorway roads (rural roads).

The actual speeds on these roads are often higher than the legal limit, indicating that many road users do not take the speed limits seriously. Differentiated speed limits, allowing for higher or lower speed limits, could be one way to improve acceptance of the speed limits. A differentiated speed limit should be based on the condition of the road and not only by putting up a sign. Accidents in rural areas are often very serious because of high speed, and typical accidents are solo accidents, head-on collisions and accidents in junctions.

On the request of members of the Danish Parliament, the Danish Ministry of Transport and Energy asked the Danish Road Directorate to suggest an approach for assessing the potential for introducing differentiated speed limits on the national rural road network. A pilot project was carried out in late 2006, and the entire state network was assessed from the first half of 2007 to the end of 2008, mainly to identify where speed limits could be increased.

1.2 Purpose
This paper presents the methodology and findings of the project carried out by the Danish Road Directorate and COWI.
The aim of the project is to identify sections where the speed limit could be increased from 80 km/h to 90 km/h without jeopardising road safety and without very expensive reconstruction of the roads. The paper describes how to systematically assess the road network when the speed limit is to be increased.

2. METHODOLOGY
The methodology for identifying sections with a potential for increasing speed limits is divided into the following activities:

- criteria for assessment of speed limits
- data collection
- screening of road network
- inspection and assessment of network
- identification of potential sections and required measures
- assessment of consequences.

The process is illustrated in figure 1 and the methodology for each step is described in the following.

![Diagram](image)

**Figure 1:** Illustration of the process of selection of road sections where a 90 km/h speed limit may be introduced.

2.1 Criteria for assessment of speed limits - step 1
Speed dependent minimum criteria on road standards, traffic, surroundings, traffic regulation etc. to be fulfilled at speed limits of 60 km/h, 70 km/h, 80 km/h and 90 km/h were identified. These are mainly based on recommendations from Danish Road Standards and experience collected in the Road Safety Handbook by The Institute of Transport Economics (TØI). The criteria are presented in table 1.
Table 1: Minimum criteria for road, traffic and accidents for assessment of speed limits.

<table>
<thead>
<tr>
<th>Desired speed limits ((v_d))</th>
<th>(v_d = 60 \text{ km/h})</th>
<th>(v_d = 70 \text{ km/h})</th>
<th>(v_d = 80 \text{ km/h})</th>
<th>(v_d = 90 \text{ km/h})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road class</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National and major regional roads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Regional roads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Local roads</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Paved width ((w))</strong></td>
<td>(7.50 \text{ m} \leq w)</td>
<td>(7.50 \text{ m} \leq w)</td>
<td>(7.5 &lt; w &lt; 8.5 \text{ m})</td>
<td>(w \geq 8.50 \text{ m})</td>
</tr>
<tr>
<td>Rec. driving lane</td>
<td>2 x 3.25 m</td>
<td>2 x 3.25 m</td>
<td>2 x 3.50 m</td>
<td>2 x 3.50 m</td>
</tr>
<tr>
<td>Min. edge lane</td>
<td>2 x 0.50 m</td>
<td>2 x 0.50 m</td>
<td>2 x 0.50 m</td>
<td>2 x 0.50 m</td>
</tr>
<tr>
<td>Min. central lane</td>
<td></td>
<td></td>
<td>1.00 m</td>
<td></td>
</tr>
<tr>
<td><strong>Min. shoulder</strong></td>
<td>2.00 m</td>
<td>2.00 m</td>
<td>2.00 m</td>
<td>2.00 m</td>
</tr>
<tr>
<td><strong>Min. safety zone</strong></td>
<td>4 m</td>
<td>5 m</td>
<td>6 m</td>
<td>7 m</td>
</tr>
<tr>
<td><strong>Non-motorised traffic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On driving lane</td>
<td>Yes/no</td>
<td>Yes/no</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Bicycle path</td>
<td>Yes (poss. lane(^{ii}))</td>
<td>Yes (poss. lane(^{ii}))</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Min. shoulder (between road and path)</td>
<td>2.00 m</td>
<td>2.00 m</td>
<td>3.00 m</td>
<td>3.00 m</td>
</tr>
<tr>
<td><strong>Min. curve radii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal curves(^{iii})</td>
<td>(\geq 510 \text{ m})</td>
<td>(\geq 790 \text{ m})</td>
<td>(\geq 1,170 \text{ m})</td>
<td>(\geq 1,820 \text{ m})</td>
</tr>
<tr>
<td>Vertical curves(^{vi})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Convex curves</td>
<td>(\geq 3,700 \text{ m})</td>
<td>(\geq 5,700 \text{ m})</td>
<td>(\geq 8,600 \text{ m})</td>
<td>(\geq 12,500 \text{ m})</td>
</tr>
<tr>
<td>Concave curves</td>
<td>(\geq 700 \text{ m})</td>
<td>(\geq 1,000 \text{ m})</td>
<td>(\geq 1,500 \text{ m})</td>
<td>(\geq 2,100 \text{ m})</td>
</tr>
<tr>
<td><strong>Side area</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accesses</td>
<td>Yes</td>
<td>Limited</td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td>No accesses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Junction density</strong></td>
<td>0-3 km</td>
<td>1-5 km</td>
<td>1-5 km</td>
<td>1-5 km</td>
</tr>
<tr>
<td>Roundabout</td>
<td>5-20</td>
<td>5-20</td>
<td>5-20</td>
<td>5-20</td>
</tr>
<tr>
<td>Signalised junctions(^{v})</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Priority junctions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>(Yes)(^{vi})</td>
</tr>
<tr>
<td><strong>Sight at junctions on primary road</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From stop line on side road</td>
<td>(\geq 195 \text{ m})</td>
<td>(\geq 225 \text{ m})</td>
<td>(\geq 250 \text{ m})</td>
<td></td>
</tr>
<tr>
<td>When turning left to side road</td>
<td>(\geq 117 \text{ m})</td>
<td>(\geq 136 \text{ m})</td>
<td>(\geq 155 \text{ m})</td>
<td></td>
</tr>
<tr>
<td><strong>Sight on sections</strong>(^{vii})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stop sight</td>
<td>(\geq 120 \text{ m})</td>
<td>(\geq 150 \text{ m})</td>
<td>(\geq 185 \text{ m})</td>
<td>(\geq 220 \text{ m})</td>
</tr>
<tr>
<td>Meeting sight</td>
<td>(\geq 150 \text{ m})</td>
<td>(\geq 190 \text{ m})</td>
<td>(\geq 240 \text{ m})</td>
<td>(\geq 290 \text{ m})</td>
</tr>
<tr>
<td><strong>Traffic and accidents</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farming vehicles</td>
<td>Limited</td>
<td>Limited</td>
<td>Limited</td>
<td>No</td>
</tr>
<tr>
<td>Actual average speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident density</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black spots</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:** i) Demands for this criterion may not be possible to apply in practise on existing roads. ii) Use of bicycle lanes instead of paths depends on the amount of car and bicycle traffic. Values for max. car traffic is indicated in “Håndbog for Tværprofiler for veje og stier i åbent land, Hæfte 3”. iii) Values cover stop sight. Horizontal curves with smaller radius (limited stop sight) may be provided with local speed limits. Radii under 400 m are generally known to be accident prone. Radii over 1,000 m are recommended for safety purposes. iv) Values cover stop sight. There should additionally be meeting sight and appropriate overtaking possibilities on two lane roads. v) Local speed limits at 60 km/h on all sections with signalised junctions. vi) Local speed limits at 60-70 km/h on all sections with priority junctions; including T-junctions, staggered T-junctions and four-leg junctions with traffic higher than 500 AADT on the secondary road. vii) Stop sight should be available on all roads. On two-lane roads there should additionally be meeting sight at design speeds \(\geq 70 \text{ km/h}\), and overtaking sight on large parts of the road at design speeds \(> 70 \text{ km/h}\).
The criteria include road class, cross sections, road side (safety zone), existence of non-motorised traffic, horizontal and vertical alignment, land use, density and type of junctions, sight distances, number of accesses, traffic level and density and frequency of accidents. It should be noted that the recommendations provided in the latest design standards are often stricter than the standards to which the existing road are designed. Accepting and/or using several minimum values of the standards has a negative impact on road safety.

The Road Directorate has decided that generally no expensive changes should be carried out during this project. A desired road safety improvement to accommodate potential higher speed limits does therefore not include actual redesign of the road such as realignment, new profiles, changes in junction layout etc.

The following criteria are considered particularly important for selecting the future speed limits on the national road network:

- paved width
- existence of paths (bicycle paths + dividing reserves) according to expected cycle traffic
- sharp horizontal curves
- sharp vertical curves
- density of junctions and accesses
- speed and accidents.

These criteria are marked with bold in the table and are used for the initial screening of the network in step 2. The consequences of the other criteria may be handled through selected improvements such as removing fixed objects, steep slopes and private accesses as well as regulation of speed and traffic by road markings and signs on sections and in junctions.

2.2 Screening of road network - step 2
Step 2 is a screening of the 2,700 km national rural network with a general speed limit of 80 km/h, with the purpose of excluding roads with no potential for higher speed limits.

Data on the road network was collected from the road data bank (VIS). The data was entered into the developed database and compared to the above criteria. Based on the road layout and on the defined criteria, the road network was divided into homogeneous sections by the database. The roads which did not meet the criteria for paved width, horizontal and vertical curves were excluded, as these are very critical parameters and it would be costly to improve roads that do not meet the criteria.

The screening resulted in a list of road sections which meet the criteria for different speed limits. The results are presented on digital maps as illustrated in figure 2. The advantage of conducting the screening of the network as a desk study is that road sections that are far from the criteria for 90 km/h, and thus generally too costly to upgrade, may be excluded at an early stage. Focus can be directed to the roads with a potential for higher speed limits, and resources may be used more efficiently during the more time-consuming inspection of the network in the field.

The roads that do not meet the criteria may - if decided by the Danish Road Directorate - be included in a full assessment of differentiated speed limits at a later stage, when the decrease of speed limits may also be considered.
2.3 Inspection and assessment of network - step 3
The 1,500 km roads screened for 80 and 90 km/h were assessed by the Road Directorate before the roads were inspected. The assessment was qualitative, estimating the potential for longer connecting sections with 90 km/h, need for road widening, facilities for cyclists, density of junctions, other accesses etc. All the sections which were not considered appropriate were excluded. The assessment was carried out by people from the Road Directorate responsible for daily maintenance and traffic activities on the roads.

The inspection of the remaining approximately 750 km roads was used to confirm data from the road database and to register issues not in the road database, such as too narrow safety zones, accesses, sight distances in junctions, etc. The safety zone is the distance from the edge of the road where ditches, fixed objects and steep slopes should be secured, e.g. by removing them or by protecting the road users by means of guardrails. For roads with a speed limit of 90 km/h the safety zone should be 7 m. Sight distances in junctions were only assessed for the roads selected as having potential for a 90 km/h speed limit.

The actual inspection of the roads was carried out with a computer connected to a GPS. The computer contained all the information from the road database, and the result of the screening was shown on a digital map. The inspectors could then register directly on the computer and via the GPS the exact location of the different issues. An example of such registrations is shown in figure 3.
2.4 Identification of road sections with a potential for higher speed limits - step 4
After the inspection, a short report on each of the homogenous sections defined in step 2 was made. The report includes the main conclusions based on the screening and inspection.

The report includes road sections which are identified as having the potential for higher speed limits (90 km/h). Also measures to avoid negative consequences on road safety were identified, and costs of the measures to fulfil the criteria described in section 2.1 were assessed. Approximately 200 km were assessed to have the potential for a 90 km/h speed limit, assuming that safety measures are applied.

The report also includes arguments for not identifying the road section as a potential candidate for 90 km/h.

2.5 Investment packages - step 5
The investment packages summarise the results from the Road Directorate. This includes the approximately 200 km road sections identified to have the potential for a 90 km/h speed limit if safety measures are applied.

The necessary safety measures and a cost are presented. It is then assessed which sections are less expensive to upgrade and how many may be upgraded at different costs. Road sections are also grouped into packages according to routes.

2.6 Assessment of consequences
The consequences of the changed speed limits were assessed. The indicators are:
The total effects on traffic accidents are a combination of the expected negative effect of higher speed, the corresponding expected increase in the number of accidents and the positive effects of improving the cross-section, safety zones, etc.

Today's situation is based on accidents registered by the police. The revised power model, describing the connection between change in average speed and accidents, and assessing the effects of the physical measures, will be used to describe the after situation. The power model is based on international studies and describes the expected development in the number of fatalities according to the following formula:

\[ A_{\text{killed after}} = A_{\text{killed before}} \cdot \left( \frac{V_{\text{after}}}{V_{\text{before}}} \right)^{4.5} \]

This means that if the speed is increased by 10 per cent, the number of fatalities will increase by more than 50 per cent.

The effect on accidents is described in four different scenarios; i) the speed is increased but no safety improvements are applied, ii) speed is increased and safety improvements are applied, iii) speed does not change regardless of higher speed limits and no safety improvements are applied and iv) speed does not change regardless of higher speed limits and safety improvements are applied.

The consequences for travel time are calculated as the difference in travel time with today's speed and the speed expected after an adjustment of the speed limit. In scenarios where the speed limit is kept, the indicator will be zero, and in scenarios where the speed is increased, the drivers will experience a shorter travel time.

The changes in emissions (CO₂, HC, NOₓ, CO, SO₂, particles) due to higher speed are only assessed qualitatively. Higher speed may lead to both increased and decreased emissions, depending on vehicle and emission type. But as only passenger cars will be affected by the higher speed limits, the changes are expected to be small.

Noise is also handled qualitatively, as only passenger cars are expected to increase speed and because the roads in question are in rural areas, i.e. located in areas with few buildings. The influence of increased speed is thus assessed to be limited as regards noise.

As with noise, the influence of increased speed is assessed to be limited for barriers to cross the road and the perception of safety, as the roads in question are located in rural areas with few buildings and consequently a limited need to cross the road.

3. RESULTS - ROADS WITH POTENTIAL FOR HIGHER SPEED LIMITS
Approximately 200 km roads on the national road network were identified for a potential speed limit of 90 km/h if the necessary safety improvements are implemented.
The identified sections are generally characterised by the fact that traffic drives faster than the present 80 km/h speed limit. The actual weighted average speed is assessed to be close to 90 km/h according to existing speed measurements.

3.1 Typical problems and measures to remedy them

There are a number of road safety problems on the sections identified for potential higher speed limits. However, the sections were selected because it was assessed that the problems could be solved at a reasonable cost.

*Typical problems and selected measures if higher speed limits*

The most common problems on the sections identified for a 90 km/h speed limit are fixed objects within the safety zone of 7 m from the edge of the road. This could be trees, stones and road furniture along the road, which it is dangerous to hit. It could also be ditches and slopes with gradients not complying with road standards.

Problems with fixed objects along the road may be handled by removing the objects or reducing the consequences if the vehicle accidentally leaves the road, by using guardrails. Ditches and slopes may be improved by flattening the slopes (>1:4) or by protection with guardrails. Sometimes part of the safety zone is located outside the road zone. In these cases guardrails may have to be used instead of removing the fixed objects.

Another type of problem are junctions and accesses for houses and fields. These are a safety problem, as traffic entering the main road will be moving slowly in the beginning, causing speed differences. To reduce the consequences of this, it is suggested to introduce lower speed limits at junctions. It is also important to ensure sight distances e.g. by cutting of vegetation etc. near junctions and accesses. As many of the junctions and accesses as possible should be closed if there is a realistic alternative.

Bicyclists should be protected by the establishment of bicycle lanes along sections suggested for a 90 km/h speed limit. As an alternative it could be considered to ban bicycle traffic on these roads, if it is possible to redirect bicyclist traffic to alternative routes, e.g. local roads. Bicycle lanes presently exist along some roads, but the shoulder between the carriageway and the bicycle lane is not always sufficiently wide. The extension of this width should be ensured before introducing a 90 km/h speed limit.

A sample of the necessary improvements and costs are illustrated and summarised in table 2.

*Costs of higher speed limits*

The total costs of introducing a 90 km/h speed limit on approximately 200 km road are assessed to amount to EUR 80 million. This is equivalent to EUR 0.4 million per km. In addition to these construction costs, there will be additional maintenance costs e.g. from increased use of guardrails.

Assuming that the roads illustrated in table 2 are sorted according to costs per km, with the cheapest first, 68 per cent or 136 km road could be improved at 50 per cent of the budget. If 90 km/h are desired on 50 per cent of the network, i.e. 100 km, this would cost approximately EUR 24.5 million or 30 per cent of the total costs if the cheapest are selected first.
Table 2: Sample of sections on the national rural road network where 90 km/h may be suggested if necessary improvements are implemented - and the respective costs.

<table>
<thead>
<tr>
<th>Road no.</th>
<th>Route no.</th>
<th>From km</th>
<th>To km</th>
<th>Length (km)</th>
<th>Necessary measures</th>
<th>Cost (million Euro)</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>11/55</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>Improve horizontal curves, ensure safety zone, secure non-motorised traffic</td>
<td>0.68</td>
</tr>
<tr>
<td>450</td>
<td>11/55</td>
<td>8</td>
<td>9.5</td>
<td>1.5</td>
<td>Ensure safety zone, secure non-motorised traffic, access control</td>
<td>0.69</td>
</tr>
<tr>
<td>450</td>
<td>11/55</td>
<td>10.9</td>
<td>15</td>
<td>4.1</td>
<td>Ensure safety zone, secure non-motorised traffic, access control</td>
<td>1.92</td>
</tr>
<tr>
<td>422</td>
<td>18</td>
<td>11.9</td>
<td>13.9</td>
<td>2</td>
<td>Improve cross-section, road marking, ensure safety zone, secure non-motorised traffic, access control</td>
<td>1.12</td>
</tr>
<tr>
<td>422</td>
<td>18</td>
<td>16.8</td>
<td>24</td>
<td>7.2</td>
<td>Improve cross-section, road marking, ensure safety zone</td>
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<td>407</td>
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<td>62.1</td>
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<td>Ensure safety zone, regulate junctions</td>
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<td>441</td>
<td>26</td>
<td>5</td>
<td>7.6</td>
<td>2.6</td>
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<td>441</td>
<td>26</td>
<td>13.5</td>
<td>16.3</td>
<td>2.8</td>
<td>Improve cross-section, road marking, ensure safety zone, access control</td>
<td>0.80</td>
</tr>
<tr>
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<td>26</td>
<td>17.4</td>
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<td>2.3</td>
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<tr>
<td>442</td>
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<td>15.9</td>
<td>18.7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td></td>
<td>79.33</td>
</tr>
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</table>

3.2 Connecting sections with higher speed limits
The potential sections are divided into 63 sub-sections on approximately 20 routes as illustrated in figure 4. Most of the potential sections have been identified on two routes, both in the western part of Denmark, with more than 30 km each as illustrated on the map. None of the identified sections are longer than 10 km, and 12 sections are identified to be between 5 and 10 km long. Some of the sections are only divided by a junction, where a local speed limit should be applied, followed by a 90 km/h speed limit. Some sections are also divided by built-up areas.
Some of the sections identified to be potential candidates for a 90 km/h speed limit are very short. More than 20 subsections are less than 2 km. It is easier for drivers to understand the indicated speed limits if the speed limits match the layout of the road. Thus these sections should, where possible, be linked to other sub-sections by improving the section in-between. The in-between sections will have more problems and thus be more costly to improve than the sections identified as potential candidates for a 90 km/h speed limit.

For example, it will be possible on a route to connect sub-sections by improving four in-between sections of 3 to 7 km length. If these four sections are changed to a 90 km/h speed limit, shorter sections could be connected to allow 90 km/h on sections longer than 10 km. By improving these four additional sub-sections, it will be possible to allow the 90 km/h speed limit on the entire route. To improve the sections, it will be necessary to establish an appropriate safety zone by removing several fixed objects, and to close and secure accesses and minor road junctions.
It will not be possible to connect two potential 90 km/h sections in all cases, for instance if the road runs through built-up areas and junctions, or in situations where costs would be very high.

Depending which strategy is chosen and the allocated budget; choosing the less expensive sections first or ensuring consistent sections, speed limits of 90 km/h may be implemented on 24-70 km, assuming a budget of EUR14 million.

3.3 Higher speed limits by route
In more practical terms it would probably be more useful to improve roads by corridors or routes. The 90 km/h speed limit would then be implemented on all sections assessed to be realistic for higher speed limits and allowing longer connecting sections. This ensures better understanding of the speed limits and consistency. With a strategy ensuring consistent sections with speed limits of 90 km/h grouped according to route number, 24-40 km of roads may be selected, assuming a budget of EUR 14 million.

4. ASSESSMENT OF POTENTIAL EFFECTS
The following section illustrates the effects to be expected if the speed limit is changed. The following factors are assessed:
- traffic accidents
- travel time
- other effects.

4.1 Traffic accidents
It is normally accepted that an increase in speed will lead to more accidents and more serious accidents. Therefore the effects on traffic accidents are assessed for the potential sections. During the period 2002-2006 approximately 20 fatalities, 100 serious injuries and 120 light injuries were registered on the 200 km roads identified as potential for higher speed limits.

Four scenarios were assessed for a possible development in traffic accidents by increasing the speed limits:
- scenario 1, where actual speed is increased and no safety improvements are applied
- scenario 2, where actual speed is increased and safety improvements are applied
- scenario 3, where actual speed is not changed regardless of higher speed limits and no safety improvements are applied
- scenario 4, where speed is unchanged regardless of higher speed limits and safety improvements are applied.

In scenario 1 it is assessed that the actual speed will increase from approximately 90 km/h today to 94 km/h by increasing the speed limits to 90 km/h. Based on international experience a 5 per cent increase in speed without any improvements of the road will lead to an increase in the number of fatal accidents by 25 per cent, an increase in the number of seriously injured of 15-20 per cent and of 5-10 per cent for minor injuries. This means that during a five-year period, an additional five fatalities are expected as well as an additional 16 serious and nine light injuries.

In scenario 2, if the increased speed is supplemented by the suggested road safety measures, such as improved cross-sections, improved safety zones, local and lower speed limits in junctions and a reduction in the number of accesses, it appears that the number of casualties (killed and injured) will not increase. However, rough assessments indicate that it could be difficult to avoid an increase in the more serious accidents (fatalities and serious injuries).
The speed will normally also increase on adjacent roads, even if there are no changes in speed limits there. As no improvements are expected on these sections, a certain increase in the number of casualties must be expected. The same is the case for junctions if the speed is not kept at the local speed limit of 70 km/h.

In scenario 3, the situation is as today, and therefore no changes are expected in the number of casualties. If safety measures are implemented and the speed is not increased, even though speed limits are increased as suggested in scenario 4, the number of fatalities, serious injuries and light injuries would be reduced by 10-15 per cent or a saving of 2 fatalities, 10 serious and 13 light injuries over a five-year period.

4.2 Travel time
An effect of higher speed limits are savings in travel time for passenger cars and vans, while trucks will still only be allowed to drive 70 km/h. The expected travel time saving by increasing the speed limit to 90 km/h is approximately 2 seconds per vehicle per km. This is under the assumption that the speed is increased from the present average speed close to 90 km/h to an after speed of 94 km/h.

4.3 Other effects
As mentioned in the methodology section, the effects of increasing the speed limits are expected to be small on both noise and emissions. This is because only passenger cars and not trucks are expected to increase speed. As the roads run through rural areas, i.e. there are few buildings, the increase in noise and emission problems is expected to be limited.

5. CONCLUSIONS
The aim of this project was to identify the potential for increasing the speed limit without jeopardising road safety. The study has shown that out of the 2,700 km roads it was possible to identify approximately 200 km roads with a potential for higher speed limits of 90 km/h. To ensure that safety is not jeopardised, investments in the order of EUR 80 million are needed.

The project also showed that the development of a database to screen the entire road network was a valuable tool in the process of assessing the roads. This saved time for inspections, as it was only necessary to visit selected roads.

The same methodology and database may be used if the Danish Road Directorate would consider introducing full differentiated speed limits, including speed limits lower than 80 km/h, at a later stage.

BIBLIOGRAPHY
Danish Road Directorate, (December 2008), Differentierede hastighedsgrænser på statsvejnettet - Report prepared by COWI.


Danish Road Directorate, (2006), Håndbog for Tværprofiler for veje og stier i åbent land, Hæfte 3.
A PRACTICAL TRAFFIC SAFETY ACTIVITY BY UTILIZING IDENTIFIED HAZARDOUS MAP DEVELOPMENT TO RAISE ROAD SAFETY AWARENESS IN THAI COMMUNITY

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ABSTRACT

In Thailand, the number of road accidents, fatalities and injuries still continues increasing, particularly, in the rural areas during the festive holidays. There are some engineering measures and one of them is an improvement of road design through road safety audit which is practical for highway engineering. The strict enforcement of traffic rules and regulation has been implemented sometimes through inspecting points to detect drunk-driving by traffic police. However, the direct measure for rising traffic safety awareness among local communities which is crucially important for traffic safety is still impractical and lacks educational.

This paper introduces a Japanese experience on community participation in hazardous spots identification (and black spots identification) to Thai communities to raise awareness on road traffic safety. Direct community-based approach was utilized through workshop and training programs at the following targeted cities: Udonthani, Samutprakarn, Khon Kaen and Chiang Mai. The results from the study show that the hazardous spots identification by community helps significantly heightening traffic safety awareness among local peoples in the communities of Thailand.
1. INTRODUCTION

In developing countries, the number of road traffic accidents and its fatalities increases rapidly at significant rate. Thailand is a good exemplified case for such rapid increase of road traffic accidents, injuries and fatalities. It is undeniable that the major cause of accidents is human error. Vehicle and road environment are a secondary cause. An integration of 5-E strategic approach has been implemented to tackle the rising traffic accidental rate in Thailand, comprising Engineering, Education, Enforcement, Emergency Medical Services and Evaluation. Some components of those are the development of a national accident database using GIS application, improvement of road conditions through the black Spot program, enforcement of motorcycle’s daytime running headlight, stringent punishment on aggressive behavior such as drunk-driving, unhelmed riders, implementation of exclusive motorcycle lane, raise public awareness on road safety and safety driving training course.

Some engineering measures such as improvement of road design through road safety audit have been brought into practice for highway engineering in Thailand in recent decade. There are numbers of advertisements and public relations campaigns televised nationwide focusing on don’t drink-n-drive to remind alcoholic drinkers on its severe adverse effects. The government even banned the TV ads of alcoholic beverages including smoking ad. However, a direct approach for rising traffic safety awareness and giving a proper traffic safety education which is crucially important for traffic safety has not been brought to real practice with local community yet.

Thus, this paper introduces an applicable Japanese experience on hazardous spots identification on local cognitive map by community so called hazardous map or “Hiyari-Map” in Japanese which has been proved to be useful for helping to raise traffic safety awareness among Japanese community peoples at large. The study employed a community-based approach utilizing a face-to-face communication tool through workshop and training program for identified hazardous spots map development with 8 local communities of the 4 selected Cities of Udonthani, Khon Kaen, Chiang Mai and Samutprakarn in north, northeastern and central parts of Thailand respectively. The target groups of the workshop included concerned government agencies, opinion leaders, traffic police, local people and students.

2. TRAFFIC ACCIDENT EXPERINECES LEARNED FROM JAPAN

Like many other developed countries, Japan had been confronted a long-drowned out road traffic accidents since 1960s. The annual number of fatalities resulting from road traffic accidents in Japan peaked at 16,765 in 1970 and dropped to 8,466 in 1979 and
continued to rise to 9,066 until 2001 when a new trend began to decline (Japan National Police Agency, 2004), see Figure 1. The significant fallen numbers of accidents, injuries and fatalities were as results of the long-running nationwide efforts of a comprehensive set of measures under the Fundamental Traffic Safety Programs. These programs consist of enhancement of the road traffic environment, widespread improvement of safety awareness, promotion of safer driving practices, advancement of vehicle safety, preservation of orderly road usage, and improvement of rescue system.

In addition to those programs, local communities, businesses, schools and other non-governmental organizations play significant role in reducing the death tolls. For instance, The Japanese government has promoted “Hiyari-Hatto map” or Hiyari-map” in short for children and elderly (i.e., let school pupils located hazardous spots nearby their house and school on the cognitive map provided and same method was introduced to elderly groups as well.) (White paper on Traffic Safety in Japan, 2004) and promotion of parents and teachers association (PTA) in teaching traffic safety education and training in school campus and their living compound and etc. These policy and practical measures have brought Japan a real success in reduction of road traffic accidents and promotion of traffic safety among their community at large.

Figure 1 Changes in road traffic accidents, deaths and injuries in Japan

3. APPLICATION OF “HIYARI-HATTO” CONCEPT
Hiyari-Hatto or Hiyari in short is a Japanese word of expression represented a feeling of danger, fear or stunningly surprise when one is facing or has seen a nearly occurred traffic accident. This Hiyari-Hatto has been used as a traffic psychological method to encourage road users to participate in the traffic safety program in order to elicit information through their experiences of nearly occurred accident that almost caused them dead or injured (which may have similar meaning to “nearniss but is not entirely the same.”) and located those hazardous spots on the cognitive map provided. This method was originally utilized for the sake of elderly peoples’ safety which currently becomes broader used to raise traffic safety awareness among schools, NGOs, local communities, etc., in Japan.

The Hiyari-Hatto concept or hazardous spot identification by community participation activity marks a quantum leap towards the substantial reduction of road traffic accidents. Recently, there are Hiyari maps (or identified hazardous spots map by community) developed by local community available on the Website (e.g., Kamagaya City, Chiba Prefecture). Figure 2 shows the local residents’ drawing their nearly occurred accidents, Figure 3 represents Hiyari map or identified hazardous spots map at Kamagaya City and Figure 4 indicates name of places where Hiyari-Hatto occurred respectively. This method provides opportunity to researchers to collect data on road safety through a participation of public on the expression of their Hiyari-Hatto which helps significantly to identify the hazardous locations prior to traffic accident occurrence. Note that the remedial measures on road traffic accident causations can be derived from this technique as well. This Hiyari-Hatto method seems applicable to raise road traffic safety awareness in Thai rural communities in terms of similarity of safety consciousness among Japanese and Thai people at large.
4. OBJECTIVE OF THE STUDY

The objectives of this study are to raise traffic safety awareness among local people in the community of Thailand and to utilize a Japanese experience of Hiyari-Hatto concept for educating local people to identify the hazardous spots in their living community and located those identified spots on local cognitive map provided so call “Hazardous map” or “Hiyari-map development” and guide them on how to avoid having accidents when passing by those hazardous spots as a tool of the traffic safety education measure.

5. SELECTION OF THE STUDY SITE AND TARGET GROUPS

The study selected 8 communities in the 4 Cities of Udonthani, Khon Kaen, Chiang Mai and Samutprakarn in north, northeastern and central parts of Thailand respectively, see Table 1.

The study targeted primarily local authorities concerned, opinion leaders, villagers, traffic police, students and community people in general with a variation of age brackets from 19 to 65 years old see also, Table 1.

6. PRACTICABILITY OF HIYARI MAP DEVELOPMENT IN THAI COMMUNITY

6.1 Research Methodology

The study employed an integrated method of 1) traffic psychology of “Hiyar-Hatto” to elicit the traffic accident information 2) community-based approach to encourage community participation, 3) face-to-face communication through workshop focused on small to medium number of participants (i.e., 14-35 participants), 4) research technique
using revealed preference (RP) questionnaire provided with asking their experiences of
the nearly occurred accidents in 3 accident contributes: car; motorcycle; pedestrian
together with providing cognitive map for locating the identified hazardous spots, and
5) GIS application for management of hazardous spots, see Figure 5. To better
understand the 3 accident contributes of car, motorcycle and pedestrian, see illustration
in Figure 6.

Table 1 Summary of Hiyari Map Development workshops in 4 Communities in
Thailand

<table>
<thead>
<tr>
<th>Study areas (Gpi/km²)</th>
<th>Venue of workshop</th>
<th>Targeted participants</th>
<th>No of participants</th>
<th>Age level</th>
<th>No of of Hiyari experiences</th>
<th>No of identified hazardous spots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nongbua community (0.5km² radius), Phayao Province</td>
<td>Community Hall</td>
<td>Local authority, opinion leader, traffic police</td>
<td>9 6</td>
<td>Mostly retirement age</td>
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<tr>
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<td>Community Hall</td>
<td>Local authority, opinion leader, traffic police</td>
<td>13 11</td>
<td>20-39: 2, 40-49: 10, 50-69: 7, 60-69: 6</td>
<td>215</td>
<td>C: 170, M: 136, P: 155</td>
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<tr>
<td>Nongbua community (0.5km² radius), Chiangmai Province</td>
<td>Community Hall</td>
<td>Local authority, opinion leader, traffic police</td>
<td>11 12</td>
<td>20-39: 2, 40-49: 10, 50-69: 7, 60-69: 6</td>
<td>215</td>
<td>C: 170, M: 136, P: 155</td>
</tr>
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</table>

Remark: C = car, M = motorcycle, P = pedestrian.
Let’s Hiyari-Map Development

1. Accident attribute - Car: Driver felt unsafe whether what would happen while driving, for instance, kid suddenly jumped on to the road

2. Accident attribute - Motorcycle: Rider felt unsafe while driving on the rough road surface

3. Accident attribute - Pedestrian: Pedestrian felt unsafe while walking on footpath

Figure 5 Integrated method for Hiyari map development

Traffic psychology: “Hiyari – Hatto”

Community-based approach

Encouragement of public participation

Face-to-face communication tool

Organization of workshop and training program

Research technique

RP face-to-face interview

Utilization of GIS application for management of hazardous spot location

Cognitive map provided to community

Hiyari Map Development

Figure 6 Illustration of 3 accident contributes: car, motorcycle and pedestrian for identified hazardous spots on Hiyari map development by community
6.2 Process of Practical Traffic Safety Education Activity using Hiyari-Hatto Concept for Hiyari map development in Thai communities

It is important to notice that successful community-based programs line in a number of common elements. A common element of successful programs was the use of multiple strategies targeted at different participants. Effective Hiyari map development programs actively involve community stakeholders/players in the program-development process to determine a program's process and goals. Utilizing multiple strategies consistent with an underlying theory of behavior change is critical to success for raising road traffic safety awareness and education. As a Hiyari map development program is spread across a community, its impact may be increased by peer pressure and modeling by other community members.

The importance of encouraging hazardous spot identification by community program or in other ward, hazardous/Hiyari map development program is that each day there may have been 3 to 600 unsafe acts occurred prior to having 1 accident fatality occurrence. The road traffic safety and accident prevention method should proactively be focusing on hazardous spots or in other word, near-misses instead of injury-related accident prevention, see Figure 7 for The Heinrich Pyramid (1931) of near-miss accidents.

**Behind one death there are 300 to 600 unsafe acts that may have been occurred everyday**

![The Heinrich Pyramid (1931)](image)

Figure 7 The Heinrich Pyramid of near-miss accidents
This study convened all the concerned parties to discuss the procedure and organization of hazardous/Hiyari map development workshop, the need in the community, identify the capacity of each party to play a role in the workshop. The processes are as follows (see also Figure 8):

1) Convened a meeting targeting at related parties concern.

2) Sought for community leadership: opinion leader of Hiyari map development workshop can be anyone like head of the community, local policeman, local government official and school teacher. In this study, the leaders who are capable to host the workshop were introduced by local authorities/coordinators.

3) Role and responsibility of the (opinion) leader: Roles of the leader involved organizing Hiyari map development workshop such as selecting the place for organizing the workshop, selecting target groups, e.g., local people in community or students, preparing materials, calling participants and moderate the session.

4) The focus was on a small group discussion of different targeted participants from 14 to 35 persons. Those are local transport officials, traffic police, head of communities, community peoples, students and representatives from charitable foundations and hospitals.

5) Organization of the workshop: The workshops had been organized at several placed including the community halls, School auditorium, University meeting and Honda Safety Riding Training Center, see also Table 1. During the workshop, presentation on traffic situation and its adverse effects like accidents, injuries and fatalities were given to targeted participants by study team. An exemplified case from Japan on Hiyari-Hatto concept was presented to make participants have some ideas before having them located identified hazardous spots so called “Hiyari map.” Then revealed preference questionnaires consisted of socio-economic characteristics, location of their house, accident experiences with drawing spatial section, cognitive map, etc., were distributed to target participants.

6) Identified hazardous spot location: After having presented Hiyari-Hatto concept, participants were given times for answering the questions and drawing the experienced nearly occurred accident site on the drawing sheet provided and asked them to locate those nearly occurred accident site so called hazardous spots on the cognitive map provided, see Figure 7. Three types of accident attribute were assigned: Hiyari experience regarding car, motorcycle and pedestrian and asked participants who experienced nearly occurred car accident, or nearly occurred motorcycle accidents or pedestrian accidents respectively.
7) Allowed participants times to brainstorm for problem-solving measures: The study team collected those data and gathered the hazardous spots identified by community participants on the master map. Then picked up only 3 major hazardous spot and invited participants to express their individual experience of nearly occurred accidents with providing reasons. Grouping them to discuss and brainstorm on problem-solving measure of the identified hazardous spots.

8) Identified hazardous sites observation: Brought community participants to the identified hazardous spot sites and advised them whether the measures they proposed were suitable to that particular spot or not, see Figures 9 - 10.

9) Evaluation of the workshop activity by questionnaire at the end of session

Hiyari map development workshop is an activity to encourage local people to be more conscious and concern on safety in their living neighborhoods. It is expected that by having the community participants identified the nearly occurred accident spots or hazardous spots or in other ward Hiyari spots, analyzed those situations and proposed measures and evaluated by local people and local government official could heighten traffic safety awareness and education. As a hazardous/Hiyari map development program is spread across a community, its impact may be increased by peer pressure and modeling by other community members.

Figure 8 Process of traffic safety education activity using Hiyari map development in community of Thailand
6.3 Identified Hazardous Spots from Developing Hazardous Map (Hiyari map)

By utilizing an integration of Hiyari-Hatto, a traffic psychological concept with public participation and cognitive map approach, it explicitly entails the significant results in terms of practical identification on the hazardous spot locations in the selected community areas. The possibility has come to realize as expected that the process by which allows local people to participate in the hazardous/hiyari map development programs for sharing the information and experiences of their potential road traffic accidents or nearly occurred accidents in their community is pragmatically adoptable.

According to the hazardous/hiyari map development workshop results, despite only less than 20 percent of participants could draw accidental location themselves and the rests were being assisted, it is amazing that they could illustrate the incidence exactly as happened. The results of cognitive map approach adoption revealed magnificent data that are used for specifically identifying the location of accident occurrence and the road.
configuration /shape of each hazardous spot as indicated in Figures 11, 12, 13 and 14. Figure 15 illustrates the accident situation based upon the identified hazardous spot by Samutprakarn students and site observation.

Figure 11 Hazardous/Hiyari map identified by community in Khon Kaen Univ., Campus

Figure 12 Hazardous/Hiyari map identified by community in Udonthani City

Figure 13 Black spots identified by students in Samutprakarn City

Figure 14 Hazardous/Hiyari spots identified by students in Samutprakarn City

Figure 15 Accident situation based upon the identified hazardous spot by Samutprakarn students and site observation.
It is obvious that most of identified hazardous spot locations were gathered at main intersections like an entrance of community and community center. However, few identified hazardous spot locations were pointed on community sub roads as well. This can be assumed that most participants got their experiences of nearly occurred accidents nearby their home or their living communities. Figure 16 shows relationship between distances from participant’s houses to identified hazardous/Hiyari spots and number of hazardous/Hiyari spots.

### 6.4 Rising Traffic safety Awareness of Participants

Before the project ended, an evaluation of hazardous map/Hiyari map development workshop program were carried out in terms of understanding of workshop contents, materials, workshop atmosphere, problems arisen during the session and responsiveness of local community toward their problem-solving measures. The results show that most of participants could actively enjoy and felt relaxing during participating in the session. The atmosphere of Hiyari map development workshop places plays a key role in stimulating local community activity. Most of participants could understand the purpose of workshop and its contents and could follow overall activity processes in accordance with the materials, i.e., manual, leaflet and presentation sheet provided, see Figure 17.

Question on awareness was asked. The results show a positive sign in that most of participants will be more concerned about traffic safety and will take care of...
themselves and the community in compliance with the traffic safety laws, see Figure 18. This result may imply that at least their awareness of traffic safety was raised and the tendency of their behavioral change had begun in a positive manner.

Figure 17 Evaluation of Hiyari map development workshop

A question on problem or difficulty on organizing hazardous/Hiyari map development workshops was raised. The cost of organizing a workshop was a priority concern and finding a leader to host a workshop was secondary issue. Hence, aiding cost or distribution of tools may be needed for organizing a Hiyari map development workshop in local community. Finding an opinion leader to organize or host the hazardous/hiyari map development workshop/program may require assistance from local authority.
concerned since the local community areas are in their jurisdiction. Figure 19 shows problematic issues of organizing Hiyari map development workshop, if it is done by local community themselves.

The study also received a very positive feedback in that each community leader who hosted the Hiyari map development workshop reported their situation of traffic safety activity after the Hiyari map development workshops were over. For instance, in Nongbua community in Udonthani, they installed speed hump at three identified hazardous/Hiyari spots after the Hiyari map development workshop. Cost of installed speed hump was paid by local authorities in charge. In Kaankheha Community in Khon Kaen (Khon Kaen Municipality), they installed traffic signal and reflective lights in two identified hazardous/Hiyari spots in their living community. In addition, they organized a traffic safety parade in their community together with local hospital. In Nonhoi Community in Chiang Mai, the community leader had proposed an improvement measure in some identified hazardous/Hiyari spots to the authority in charge. However, the proposal was not approved because of insufficient budget allocation.

![Figure 19 Problem issue of organizing Hiyari map development workshop](image)

6. CONCLUSION

This paper presents a community-based approach for practical activity of traffic safety awareness raising by encouraging local community people to identify hazardous/hiyari...
spots that they experienced or have seen the nearly occurred accidents in their living communities for development of hazardous/Hiyari Map workshop program in Thailand.

In the workshops the following program was carried out. First, the concerned government agencies/local authorities, community leaders, local people and students were invited to discuss and exchange their opinions toward the traffic situation, accidents and traffic safety in their living communities. Later, the study team introduced a Japanese experience of letting local Japanese people to identify hazardous spots and locate them on the local cognitive map. Then let local participated community people exercised identifying the hazardous spots and locate them on the map provided. Fourth, asked local people to explain why they thought those identified spots are hazardous. Finally, brought the local people to see the sites that they identified as hazardous spots and encourage them to figure out how to temporary solve the problem prior to asking for the government assistance.

The results from this pilot study indicate significant outputs in that the level of traffic safety awareness among not only participants but also other people in the community has been improved. The information on hazardous spots (and also black spots) were able to collect at the same time from the workshops which also were quantified enough to develop a database and analyzed the accidental situations for problem-solving on sites. A direct approach of community-based program for hazardous/Hiyari map development workshop triggered traffic safety activity in community and raised traffic safety awareness among local participants.

However, there were also problems and difficulties took place. The major problems of the study are data unavailability of existing black spots to compare with our study and the process to let participants draw the map of nearly occurred accidental locations and situations that they had seen or experienced with. It is apparent that majority of participants could not draw the map despite their regular road users of that area and needed some kind of assistance from the study team to tell the direction. These problems led to a difficulty to identify the crash characteristics and hence contributing to the delay in conducting the sessions.

Nevertheless, these hazardous/Hiyari map development workshop programs were quite successful programmatic elements which designed for community-based trials. The evaluation methodology used also influence program effectiveness. The workshop programs used a randomization of groups and selective communities that have similar characteristics—such as socioeconomic status, age, and safety behavioral consciousness that may considerably be influential factors of the effectiveness of the program. In order to sustain this practical traffic safety activity, a technical and financial assistance from the government and private sector may be needed.

REFERENCES


International Association of Traffic and Safety Sciences. (2000). *Hiyari tizu zukuri no teian no seika to sono unyou ni kansuru kenkyu* [Study on result of suggestion and management of Hiyari map development].


IMPLEMENTING TRAFFIC SAFETY COMMUNITY-BASED ACTIVITY FOR DEVELOPMENT OF TRAFFIC SAFETY CULTURE IN VIETNAM

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ABSTRACT

The continual increase of avoidable road traffic accidents, injuries, fatalities has generated a massive loss of human resources, property damages and economy of the country of Vietnam. The study of “National Road Traffic Safety Master Plan until 2020” has been completed this year which can be considered as the significant threshold of the development and improvement of human resources, quality of life and social welfare of Vietnamese citizens. In this study along with other proposed strategic countermeasures, traffic safety culture development is proposed to the Government of Vietnam in hoping that with cooperation among all agencies concerned and community participation this would help sustainably changing road users from high risk-taking behavior to proper and law-abiding behavior.

This paper also presents the results of a community-based pilot study of traffic safety culture activity on “Safe-Route-To-School Program of Tan Truong Commune, Cam Giang District, Hai Duong Province, Vietnam.

1. INTRODUCTION

The Global Road Safety Partnership (GRSP) statistics reports that nearly 1 million people are killed and more than 10 million peoples are injured in road traffic accidents at average global rate. More than 75\% of those occurred in developing and transitional countries.

According to the traffic accident data of ASEAN countries, see Table 1, the level of traffic safety in Vietnam is considerably low. Regarding the total number of fatalities, Vietnam ranked third after Thailand and Indonesia in 2000. However, this has overtaken them to become Number 1 in 2006. Table 2 indicates the road traffic accidents in Vietnam per 10,000 persons with increased rate from 1990 to 2006. The data collected from National Traffic Safety Committee (NTSC) and Police indicate that most of accidents took place at the areas along national highways, especially, highways near a school complex contributing to high vehicle speeds. A tendency of accidents by students and youths will possibly reach to an epidemic proportion if no urgent remedial action takes place to change Vietnamese road
users’ attitude and behavior when participating in road traffic along the national highways in particular.

This paper introduces traffic safety culture which is a concept that utilized together with developed transportation system in many countries and has been realized with a likely successful rate of return in reduction of number of accidents and fatalities. These gained experiences would offer Vietnam the significant valuable lessons. Traffic safety culture activity can be applicably realized in schools and their central and local organizations concerned playing key roles, in cooperation with communities. The cooperation will be effective as long as schools and communities recognize safety’s significance to students and local residents.

Table 1 Comparison of road traffic accidents among ASEAN Countries (2000)

<table>
<thead>
<tr>
<th>Country</th>
<th>Populations (000)</th>
<th>Motorized Vehicles (000)</th>
<th>No of Accidents</th>
<th>No of fatalities</th>
<th>Per 100000 populations</th>
<th>Per 10000 vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam (2006)</td>
<td>84,500</td>
<td>19,589</td>
<td>14,727</td>
<td>12,757</td>
<td>1.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Vietnam (2000)</td>
<td>77,635</td>
<td>6,695</td>
<td>23,327</td>
<td>7,924</td>
<td>1.0</td>
<td>11.8</td>
</tr>
<tr>
<td>Brunei</td>
<td>338</td>
<td>213</td>
<td>2,861</td>
<td>41</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Cambodia</td>
<td>12,000</td>
<td>331</td>
<td>556</td>
<td>196</td>
<td>0.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Indonesia</td>
<td>210,400</td>
<td>18,224</td>
<td>13,000</td>
<td>9,500</td>
<td>0.5</td>
<td>5.2</td>
</tr>
<tr>
<td>Laos</td>
<td>5,300</td>
<td>187</td>
<td>3,159</td>
<td>362</td>
<td>0.7</td>
<td>19.1</td>
</tr>
<tr>
<td>Malaysia</td>
<td>23,300</td>
<td>10,590</td>
<td>250,417</td>
<td>6,035</td>
<td>2.6</td>
<td>5.7</td>
</tr>
<tr>
<td>Myanmar</td>
<td>47,700</td>
<td>424</td>
<td>3,459</td>
<td>1,021</td>
<td>0.2</td>
<td>24.3</td>
</tr>
<tr>
<td>Philippines</td>
<td>75,600</td>
<td>3,506</td>
<td>10,595</td>
<td>969</td>
<td>0.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Singapore</td>
<td>4,000</td>
<td>689</td>
<td>77,475</td>
<td>189</td>
<td>0.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Thailand</td>
<td>60,700</td>
<td>19,728</td>
<td>67,800</td>
<td>12,040</td>
<td>2.0</td>
<td>6.1</td>
</tr>
<tr>
<td>Japan</td>
<td>129,260</td>
<td>89,250</td>
<td>917,609</td>
<td>9,066</td>
<td>0.7</td>
<td>1.0</td>
</tr>
</tbody>
</table>


Table 2 Road Traffic Accidents per 10,000 persons with Annual Increased Rate (1990-2006)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Accidents</th>
<th>Growth Rate (%/yr.)</th>
<th>No. per 10,000 persons</th>
<th>No. of Fatalities</th>
<th>Growth Rate (%/yr.)</th>
<th>No. per 10,000 persons</th>
<th>No. of Injuries</th>
<th>Growth Rate (%/yr.)</th>
<th>No. per 10,000 persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>6,110</td>
<td>-0.9</td>
<td>2,268</td>
<td>-0.3</td>
<td>4,956</td>
<td>-0.7</td>
<td>735</td>
<td>-0.7</td>
<td>1,268</td>
</tr>
<tr>
<td>1991</td>
<td>7,382</td>
<td>20.8</td>
<td>2,602</td>
<td>14.7</td>
<td>7,114</td>
<td>45.3</td>
<td>199</td>
<td>20.8</td>
<td>4,672</td>
</tr>
<tr>
<td>1992</td>
<td>9,470</td>
<td>28.3</td>
<td>3,077</td>
<td>18.3</td>
<td>10,048</td>
<td>41.2</td>
<td>2,289</td>
<td>28.3</td>
<td>6,290</td>
</tr>
<tr>
<td>1993</td>
<td>11,582</td>
<td>22.3</td>
<td>4,140</td>
<td>34.5</td>
<td>11,854</td>
<td>18.0</td>
<td>3,686</td>
<td>22.3</td>
<td>7,978</td>
</tr>
<tr>
<td>1994</td>
<td>13,760</td>
<td>18.8</td>
<td>4,897</td>
<td>18.3</td>
<td>14,174</td>
<td>19.6</td>
<td>4,477</td>
<td>18.8</td>
<td>9,954</td>
</tr>
<tr>
<td>1995</td>
<td>15,999</td>
<td>16.3</td>
<td>5,728</td>
<td>17.0</td>
<td>17,167</td>
<td>21.1</td>
<td>5,055</td>
<td>16.3</td>
<td>11,112</td>
</tr>
<tr>
<td>1996</td>
<td>19,638</td>
<td>22.7</td>
<td>5,932</td>
<td>3.6</td>
<td>21,718</td>
<td>26.5</td>
<td>6,390</td>
<td>22.7</td>
<td>13,382</td>
</tr>
<tr>
<td>1997</td>
<td>19,998</td>
<td>1.8</td>
<td>6,152</td>
<td>3.7</td>
<td>22,071</td>
<td>1.6</td>
<td>6,733</td>
<td>1.8</td>
<td>13,506</td>
</tr>
<tr>
<td>1998</td>
<td>20,753</td>
<td>3.8</td>
<td>6,394</td>
<td>3.9</td>
<td>22,989</td>
<td>4.2</td>
<td>7,174</td>
<td>3.8</td>
<td>14,354</td>
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<tr>
<td>1999</td>
<td>21,538</td>
<td>3.8</td>
<td>7,095</td>
<td>11.0</td>
<td>24,179</td>
<td>5.2</td>
<td>7,863</td>
<td>3.8</td>
<td>15,732</td>
</tr>
<tr>
<td>2000</td>
<td>23,327</td>
<td>8.3</td>
<td>7,924</td>
<td>11.7</td>
<td>25,693</td>
<td>6.3</td>
<td>8,548</td>
<td>8.3</td>
<td>17,156</td>
</tr>
<tr>
<td>2001</td>
<td>25,831</td>
<td>10.7</td>
<td>10,866</td>
<td>37.1</td>
<td>29,449</td>
<td>14.6</td>
<td>9,182</td>
<td>10.7</td>
<td>18,364</td>
</tr>
<tr>
<td>2002</td>
<td>27,993</td>
<td>8.4</td>
<td>13,186</td>
<td>21.4</td>
<td>30,999</td>
<td>5.3</td>
<td>9,620</td>
<td>8.4</td>
<td>19,547</td>
</tr>
<tr>
<td>2003</td>
<td>20,774</td>
<td>-25.8</td>
<td>11,864</td>
<td>-10.0</td>
<td>20,704</td>
<td>-33.2</td>
<td>10,152</td>
<td>-25.8</td>
<td>21,016</td>
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<tr>
<td>2004</td>
<td>17,663</td>
<td>-15.0</td>
<td>12,230</td>
<td>3.1</td>
<td>15,417</td>
<td>-25.5</td>
<td>10,603</td>
<td>-15.0</td>
<td>16,068</td>
</tr>
<tr>
<td>2005</td>
<td>14,711</td>
<td>-16.7</td>
<td>11,534</td>
<td>-5.7</td>
<td>12,013</td>
<td>-22.1</td>
<td>11,054</td>
<td>-16.7</td>
<td>16,621</td>
</tr>
<tr>
<td>2006</td>
<td>14,727</td>
<td>0.1</td>
<td>12,757</td>
<td>10.6</td>
<td>11,288</td>
<td>-6.0</td>
<td>11,534</td>
<td>0.1</td>
<td>17,210</td>
</tr>
<tr>
<td>2007</td>
<td>13,985</td>
<td>-5.0</td>
<td>12,800</td>
<td>0.3</td>
<td>10,266</td>
<td>-9.1</td>
<td>12,013</td>
<td>-5.0</td>
<td>18,021</td>
</tr>
</tbody>
</table>

Source: National Traffic Safety Committee (NTSC)

Hence, raising awareness on road traffic safety among school, students and local residents as well as other road users passing by and the concerned authorities should be the primary step. Thus, the study implemented a pilot project on “the Safe-Route-to-School program” to the local community. The Cam Giang High-school is selected and the pilot target as it located
along the national highway No. 5 in Tan Truong Commune, Cam Giang District, Hai Duong Province. The Safe-Route-to-School program is the first pilot project ever implemented in Vietnam as one of the traffic safety culture development activities under the study of National Road Traffic Safety Master Plan by NTSC in cooperation with JICA.

2. PURPOSES/ OBJECTIVES

The purposes of the pilot project are:

- To introduce a practical traffic safety culture activity through a pilot project;
- To identify the coordinating organizations that play a key role in implementing the traffic safety culture activity in provincial school along the national highways (e.g., NTSC, PTSC, DTSC, DoET, Police, DoT, local people committee, Community, School-headmaster, and so forth); and

The objectives of the Safe-Route-to-School program” are to

- To raise awareness on traffic safety in the school and the community by introducing the “Safe-Route-to-School” program
- To educate high-school students how to bike and walk to school safely
- To encourage the community to instruct traffic safety for students and local residents, to generate cultural and civilized behaviors

3. EXPRESSION OF TRAFFIC SAFETY CULTURE

Traffic safety education, including development of traffic safety culture is a long-term consistent process that compresses communication and information dissemination to raise public awareness, institutional development (including enforcement), so that road users’ attitudes and behaviors can be sustainably changed. Daily practices of proper road using behavior would accumulatively internalize an individual attitude, develop into a safe habituation and naturally implant to traffic safety culture.

The success of traffic safety culture development lies in the enthusiasm and commitment of the authorities concerned and the communities in particular to work together towards a common goal of increasing awareness and reducing the number of road traffic accidents. This traffic safety culture development is therefore aimed at help building capacity towards sustainable development.

4. SAFE-ROUTE-TO SCHOOL (SRTS) DEFINITION AND ITS APPLICATION

Safe-Routes-to-School is a method to encourage school students including those with disabilities, to walk and bike to school - and to make walking and bicycling to school safely and appealing and more aware of the potential dangers they face in walking or biking to and from school with effort and cooperation among local authorities, police, local road authority, communities, schools, and parents to make routes safer for students to walk or bike to school. Each day a large number of students walk or ride their bikes to and from Schools. These students need to be educated and/or reminded of traffic safety rules and regulations.

Safe-Routes-to-School (SRTS) program has been introduced to many community schools in Europe, United States, Canada, Australia and New Zealand. The term “Safe Routes to School” was first used in Denmark in the late 1970s as part of an initiative to reduce the number of children fatalities while walking and bicycling to school.
Most of Safe Routes to School programs are built on collaborative partnerships among many stakeholders including educators, parent, students, elected officials, engineers, city planners and engineers, business and community leaders, health officials, and bicycle and pedestrian advocates. The most successful SRTS programs incorporate the five (5) E’s countermeasures consisting of education, engineering, enforcement, encouragement and evaluation. The goal of Safe Routes to School is to get more children bicycling and walking to schools safely on an everyday basis.

While there are numbers of Safe Routes to School programs implemented in developed countries, there is only a very limited number of SRTS study done in developing countries in Asia. Hence, an introduction of SRTS program to Vietnam may consider a pioneer study.

5. CURRENT TRAFFIC SAFETY EDUCATION IN SCHOOLS IN VIETNAM

The traffic safety education in schools is characterized in Table 3 below.

Table 3 Current traffic safety education in schools

<table>
<thead>
<tr>
<th>School level</th>
<th>Traffic safety education program</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High-school</td>
<td>Integrate in Law Education</td>
</tr>
<tr>
<td>2. Secondary school</td>
<td>Integrate in appropriate classes in curriculum Integrate in Civil Education:</td>
</tr>
<tr>
<td></td>
<td>- 6th grade: 23rd and 24th classes – “Ensure Traffic Safety Order”</td>
</tr>
<tr>
<td></td>
<td>- 7th to 9th grades: 18th class “Extra-Curriculum Practice and Local Issues”</td>
</tr>
<tr>
<td>3. Elementary school</td>
<td>From the 3rd week of September to 2nd week of November – 1 class per week</td>
</tr>
<tr>
<td></td>
<td>- 5th grade: 5 lessons in 8 classes</td>
</tr>
<tr>
<td></td>
<td>- 1st to 3rd grades: 6 lessons in 8 classes</td>
</tr>
<tr>
<td>4. Kindergarten</td>
<td>Traffic safety topic in 2-3 weeks of the 2nd semester</td>
</tr>
</tbody>
</table>

Notes: In addition, traffic safety is also integrated in extra-curriculum activities hosted by the Youth Union, Red Cross Foundation and Teenager Union every Monday and in weekly discussion. Students’ profiles also include their records of traffic violation. September is the month of Traffic Safety.

Source: DOET and JICA study team.

6. SITE SELECTION FOR PILOT PROJECT

In this study, along with other proposed strategic countermeasures of the study on “National Road Traffic Safety Master Plan until 2020,” traffic safety culture development is proposed to the Government of Vietnam in hoping that with cooperation among all agencies concerned and community participation this would help sustainably changing road users from high risk-taking behavior to proper and law-abiding behavior. A pilot activity can be a significant model for information dissemination, duplication or modification into other areas.

The selected target area needs to benefit both the school and the local community. Two parties must have goodwill to carry out traffic safety activities. Also proposed activities will create favorable conditions if they want to continue later on.
Hence, in cooperation and suggestion of NTSC and other concerned agencies, the pilot project has selected Cam Giang High-school as a pilot site and their students as a primary target. The Cam Giang High-school is located along the national highway No. 5 in Tan Truong Commune, Cam Giang District, Hai Duong Province. The “Safe-Route-To-School” program has scoped the area for pilot study within 500-1000m radius covering an area from Ghe intersection to Cam Giang High School see Figure 1 below.

An integration of 3 significant countermeasures of engineering, education and enforcement in particular together with encouragement of public participation was employed to implant awareness of Vietnamese road users to behave in proper manner and be considerate of other road users when involving in road traffic.

Traffic safety education, including traffic safety culture is a long-term and constant process that compresses communication and information dissemination to raise public awareness, institutional development (including enforcement), so that road users’ attitudes and behaviors can be sustainably changed. Daily practices of proper road using behavior would accumulatively internalize an individual attitude, develop into a safe habituation and naturally implant to traffic safety culture.

![Figure 1 Location Map of the Pilot Site in Cam Giang District, Hai Duong Province.](image)

6.1 Characteristics of the Pilot Project Site

6.1.1 General Situation of Cam Giang High School in Hai Duong Province
Cam Giang High School’s main entrance is on the National Highway No.5 and around 200 meters away from Ghe intersection. The school covers an area of 27,445 square meters; have total numbers of 69 teachers and 1,391 students with 30 classes. Most teachers commute to school by motorcycles while almost all of students (95%) ride bicycles to school.

The route from Ghe intersection to the school configures a small slope with a bottleneck section. Most of teachers and students use this route to access to school. As local
residents (retailed shops) are illegally occupied the area, it becomes even more difficult for students and teachers to access the school, see Figure 2. Some who live on different direction from school have to cross the NH No.5 as coming to and leaving school. Apparently, traffic safety is a major issue to the school. Although having proposed the problem to authorities many times, the issue has not been solved.

General situations of safety concerns in Cam Giang High School are as follows.

- Cam Giang High-school has more than 1300 students and most of them walk or bike to school from home daily in approx 5 to 7 km of travel distance.

- Cam Giang High-school situated on NH No. 5 which is an international highway where industrial zone located and lots of accidents frequently occurred.

- More than 100 students and local residents use and cross the roads at Ghe intersection daily.

- High-school students have a high tendency of risk taking behavior and low perception of risk as the more risking behaviors they perform the more respect and admire they receive from their friends.

- Once the students do running red-light, the others follow generating potential road traffic accidents and hence becoming a social dilemma.

Figure 2 Cam Giang High-School entrance and the narrow slope with bottle-neck path accessing to school where motorcycle taxi stop and retail shop illegally occupied the road shoulder space.
6.1.2 Traffic Safety Education in Cam Giang High-School
The traffic safety education subject is taught mostly integrated with Civil Education. The subjects related to traffic safety education are also combined with geography or foreign language. Traffic safety education was included in both official and extra curriculum.

6.1.3 Traffic Safety situation in the school
Based upon the survey, the total numbers of accident involved with students in the past 3 years are 40 which contributed to five percent injury while the total numbers of accident involved with teachers are 5.

There were numbers of students involved in the accidents. One student had been hit 3 times by motorcycles but no serious injury (Nguyen Cao Dung- 12C2 Class). Another student had also been hit 3 times by motorcycles which caused a serious injury (Le Mai Ngan-11B1 Class). Surprisingly, one student had been hit more than ten times and serious injured.

The major causations of accident were inappropriate lane separation, narrow roads and road users’ risk-taking behaviors. The indicated risk-taking behaviors are parallel riding, chatting or carrying umbrella while riding, one rider carrying 2 or 3 passengers, speeding, illegal overtaking, overloading, jaywalking and careless crossing.

6.2 Characteristics of Traffic Situation at Ghe Intersection
Ghe intersection on the national highway No. 5 in Tan Truong Commune is one among intensified transportation activity spots where 6 public and private schools, industrial complex, public utilities, fresh markets, retailed shops and local residents are located surrounding. Each day more than 100 primary to high school students, parents, teachers, other road users use or cross the road at Ghe Intersection. Sometimes the avoidable human caused accidents occur with either student pedestrians or bicyclists or adult drivers or vice versa, see Figure 3.

Figure 3 Large number of students crossing the road at Ghe Intersection daily
The flashing yellow lights are operated at most intersections along the national highways including Ghe intersection to alleviate high traffic volume and to smooth traffic flow. The motor vehicle drivers tend to drive at speeds that they feel
comfortable with while vulnerable road users like student pedestrians and bicyclists try to cross the roads at Ghe intersection with passing-by speedy motor vehicles condition. In addition, there are other concerns relative to traffic engineering problems which can be contributing to the causes of accident occurrence. Those are:

(i) Non-signalized operation  
(ii) Unclear crosswalk marking  
(iii) Insufficient pedestrian crossing signage.  
(iv) Motorcycle taxi stop occupied the road shoulder and obstruct the passage of sidewalk and the access to school for students and pedestrians  
(v) Encroachment of retailed shops which obstruct the passage accessing to school

There are numbers of accident frequently occurred at Ghe intersection. According to a visual observation at site and the report from local traffic police of Tan Truong Commune and Cam Giang District indicate major causes of accidents, these are:

- Speeding  
- Overtaking, passing over  
- Cut-across the running vehicles  
- Not yield to pedestrians  
- Jaywalking, crossing the road while using gadget devices  
- Parallel riding and so on

Nevertheless, a traffic-survey has been conducted prior to implementation of a pilot project for quantitative analysis of traffic situation at Ghe intersection.

6.2.1 Traffic Survey at Ghe Intersection

Traffic count survey was conducted at Ghe intersection before implementation of pilot project in order to understand the traffic situation. The method of data collection is indicated in Table 4 and its results are shown in the following figures.

<table>
<thead>
<tr>
<th>Survey Coverage:</th>
<th>This survey was conducted 1 day (24 hours) at Ghe intersection along NH5, on Jan. 7 - 8, 2009.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Method:</td>
<td>The traffic count survey was conducted to get the hourly traffic volume by vehicle type and by direction. The vehicle type is classified as follows:</td>
</tr>
<tr>
<td></td>
<td>1) Pedestrian                                      9) Private Bus</td>
</tr>
<tr>
<td></td>
<td>2) Bicycle                                         10) 2-Axle 4-Wheel. Truck</td>
</tr>
<tr>
<td></td>
<td>3) Cyclo / rickshaw                                11) 2-Axle 6-Wheel. Truck</td>
</tr>
<tr>
<td></td>
<td>4) Motorcycle                                      12) 3-Axle Truck</td>
</tr>
<tr>
<td></td>
<td>5) Car                                             13) 4 or More Axle Truck</td>
</tr>
<tr>
<td></td>
<td>6) Taxi                                            14) Trailer</td>
</tr>
<tr>
<td></td>
<td>7) Mini Bus (&lt;=25 pax)                             15) Others</td>
</tr>
<tr>
<td></td>
<td>8) Standard Bus (&gt;25 pax)</td>
</tr>
</tbody>
</table>
Daily Traffic Volume

The traffic volume on NH 5 is more than 30,000 vehicles per day. The share of the two-wheeled vehicles and the four-wheeled vehicles is almost identical. The traffic volume Direction of Cam Giang and Hung Yen is more than 10,000. Majority of them are bicycles and motorcycles, see Figure 4.

Hourly Traffic Volume

There are 2 peak hours at around 8 o'clock and 18 o’clock at this intersection. It seems that traffic situation is getting complicated during these hours, see Figures 5 and 6.
6.2.2 Traffic Safety Awareness of Local Residents

In the interview survey, the samples of 107 residents were distributed to local residents who live nearby Ghe intersection asking their level of traffic safety awareness prior to implementing the pilot activity. The questionnaire used in this survey composed of traffic behavior at Ghe intersection, opinion on traffic safety, traffic accident experience and personal information sections.

As indicated in Figure 7, major findings are as the followings.
(i) Almost all of road users feel dangerous when they cross at Ghe intersection.
(ii) Majority of road users feel dangerous during peak hours (6:00-8:00, 16:00-18:00).
(iii) Major reasons of road traffic unsafe are “People’s driving manner” and “Lack of traffic lights and signs.”
(iv) It is most important that traffic lights and signage should be operated to improve traffic safety at Ghe intersection.
(v) Another significant issue is that it is required the operation of traffic signal at least peak hours to keep traffic safety and smooth traffic at Ghe intersection. In addition, traffic safety culture activities by traffic police and local volunteers are requested to protect vulnerable road users and to promote awareness of road users while traffic signal is in operation.
7. IMPLEMENTATION OF PILOT PROJECT ACTIVITY

The conceptual procedure was developed and followed to simplify the implementation of pilot project. The conceptual flowchart of the pilot project implementation process is illustrated in Figure 8 below.

Implementation of a pilot project on Safe-Routes-to-School program required a comprehensive action plan to assist students in the development of safe walking or riding habits, the identification of safe routes and to make them more concerned and aware of the potential risks / dangers they face in walking to and from school daily.
7.1 Implementation of Program Activities

It is vital important for achieving the objective of raising traffic safety awareness is to make students and other agencies concerned participating, experiencing and practicing in the activity. In the pilot project of traffic safety culture development, two program activities were launched:

(i) **Program Activity 1: Traffic Safety Culture (TSC) Student Activity Corner**

*This program* is a school-based activity and students are a primary target. 

*Its objectives* were to raise awareness and to stimulate student participation in traffic safety culture in school.

*Activity site* is on campus of Cam Giang High School.

*Duration for TSC student activity corner* was one day activity on 12th January 2009. The allocated duration for activity was approximately 1 hour (from 09:40 to 10:40).

**Details of the TSC student activity corner program consisted of:**

- Quiz time (Q & A) (allocated time: 20 min.) The main reason of choosing the quiz time as the first program was for stimulating and motivating students to participate in the event. And most importance was to know the level of their traffic safety educational background. The following procedures were performed:
  - 15 Questions of traffic rules and traffic signs were developed by local traffic police;
  - Students felt free to participate and answer the questions;
  - Students who answered the questions correctly were presented a token of gift prepared by JICA study team;
  - The event took place on the ceremonial stage and performed...
by local traffic police and students.

- Demonstration on how to bike-n-walk to school safely and what aggressive behaviors should be avoided (allocated time: 20 min.) After having known the students’ traffic safety educational background through quiz time of traffic rules and traffic signs, the demonstration of aggressive behaviors were taken place to remind/reiterate students of laws imposed on these behaviors. The following procedures were demonstrated:
  - 10 trained volunteer students were performed the 3 high risk riding behaviors (these high risk behaviors were selected based upon accidents record from the school and local traffic police) with a close instruction of local traffic police.
  - The demonstration was performed to the crowd of students and other participants with given proper instructions why these kinds of aggressive/high risk behaviors should be avoided.
  - The demonstrated location was on campus in between the ceremonial stage and the roadway to classroom building.
  - The event was conducted by school and students in cooperation and under a close supervision of local traffic police.

- TSC student activity corner at student information section (20 min.) This last but not least program was provided to the students the information of traffic safety education along with the simple questionnaire so as to know their reaction and feedback. The event procedures were:
  - Asked students to fill out questionnaire and presented toolkits for incentive program
  - The questionnaire was developed by students and JICA study team
  - Invited students to be a member of TSC student activity corner for future activity purpose and
  - PR how to access TSC youth club website and Distribute TSC tool kit
  - The session conducted by volunteer students, see Figures 9, 10, 11 and 12.
• **Materials use for this activity:**

  In order to grasp attention and have strongly significant impact on all agencies concerned and participants particularly on influencing over neighboring cities, the event had launched in attractive and informative environment such as

  a) Decoration of the activity corner

    - The student information section on campus was used for installation of tables, chairs, table cloths as the booth of TSC student corner
- 3 Poster stands of “Traffic Safety Culture Student Activity Corner” were designed and placed. One poster stand illustrated the traffic signs and traffic rules while another focused message on “Toward kindhearted traffic accident free society” and the last demonstrated the traffic safety education and traffic safety culture in Japan and the like to influence and grasp attention of students and other participants.

b) Materials use for the activity
- Stationary, e.g., pen, pencil, eraser use for filling in questionnaire and sign in were provided.
- TSC toolkit, e.g., traffic safety reading materials, leaflet, notebook, pen or pencil key holder, traffic safety reflective stickers were provided for incentive program.

(ii) Program Activity 2: Traffic Safety Patrol Program
This program is a community-based activity. Students and local residents are a primary target. Details of the traffic safety patrol program consisted of:

Key measure: Utilization of safety Patrol program at Ghe intersection, Tan Truong Commune, Cam Giang District, Hai Duong Province.

Significant supportive measures: Improvement of road environment and signage was carried out.

Its objectives were to raise awareness and to stimulate local resident participation in traffic safety culture along Ghe intersection down to Cam Giang High School campus.

Activity site is at Ghe Intersection on the national highway No. 5.
Scale of activity area covers an area of 500 – 1000 meters radius from Ghe intersection to the school campus, see Figure 12 below.

Source: JICA study team.

Figure 12 Illustration of Safety Patrol Program at Ghe Intersection.
Duration and operation of traffic safety patrol program: This program was 10 days operation kicked off from 12th to 21st January 2009. Owing to the temporal (the pilot project took place quite close to the Tet Holiday) and budgetary limitations associated with a complication of local authorization on traffic signal operation, the traffic safety patrol program could only allowed to perform their crossing guards in the operational period as follows:

1) The 10 local volunteers were recruited for training to be the crossing guards in traffic safety patrol program to help students and other road users crossing streets at Ghe Intersection safely.
2) Assigned position, function and responsibility required for safety patrol volunteer activity are indicated in Table 5.
3) These 10 trained local volunteers so called crossing guards were assigned to assist students and other road users crossing the 4-direction of streets at Ghe Intersection from Morning school peak: 06:30 – 07:30 and Afternoon school peak: 17:00 – 18:00
4) The performance only took place twice a day per 10 days from 12th to 21st January 2009 (before the Tet Holiday).
5) The traffic instruments were used to accommodate the crossing guards during its operation.
6) The numbers of local traffic police were closely and strongly supervised the crossing guards during the operational period.
7) The traffic signals were eventually allowed to operate during the pilot project period, see Figure 13.

Table 5 Function and responsibility required for safety patrol volunteers

<table>
<thead>
<tr>
<th>Position</th>
<th>Function and (Job) Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing guard of Traffic Safety patrol program</td>
<td>- Conduct a safety patrol by standing on crosswalk of each Direction at Ghe intersection.</td>
</tr>
<tr>
<td></td>
<td>- Observe traffic volume and wait for crossing light turns green then using safety</td>
</tr>
<tr>
<td></td>
<td>instruments provided to gesture pedestrians while assisted crossing the roads.</td>
</tr>
<tr>
<td></td>
<td>- Help student pedestrians safely crossing roadways during morning school</td>
</tr>
<tr>
<td></td>
<td>peak hour and afternoon school peak hour.</td>
</tr>
<tr>
<td></td>
<td>- Instruct road users for the inappropriate behaviors with close supervision of traffic</td>
</tr>
<tr>
<td></td>
<td>police.</td>
</tr>
<tr>
<td></td>
<td>- Give caution to those who violate traffic laws or high risk behavioral road users with close</td>
</tr>
<tr>
<td></td>
<td>supervision of traffic police.</td>
</tr>
</tbody>
</table>

Figure 13 Picturesque activities of traffic safety patrol program at Ghe Intersection
• Materials use for the activity:

In order to make the Ghe intersection safer for students, local residents and other road users, and to make the pilot project stronger impact and influence over all agencies concerned and participants, particularly other neighboring cities, the event has proposed to improve the following instructive environment, see Figure 14.

a. Installation of traffic sign/signage of Pedestrian crossing
b. Repaint crosswalk marking of four directions, see figures below
c. Materials use for crossing guards in the safety patrol program activity
   - 2 Loudspeakers
   - 10 whistles
   - 4 medium size flags
   - 10 safety reflective vests with TSC text
   - Nametag of safety patrol volunteers/activists
   - Stationary, e.g., pen, notebook (for taking note, etc.)

![Figure 14 Picture of proposed repainting crosswalk marking at 4 directions.](image)

8. ANALYTICAL RESULTS OF THE TRAFFIC SAFETY CULTURE ACTIVITY PROGRAM ON SAFE-ROUTE-TO-SCHOOL PILOT PROJECT

8.1 Survey Results from students in Cam Giang High-School

The survey was conducted with 38 students one day before the project ended. The questions were focused on the usefulness and effectiveness of the program activities in the safe-route-to-school pilot project implemented as a part of traffic safety culture activities. The results indicated:

(i) By having seen the demonstration of the 3 risk behaviors of the pilot program, 33 students (32/38 students) indicated that risky behavior demonstration was helpful and they acknowledged the danger in local traffic while pointing out risky behaviors of pedestrians and bicyclists.

(ii) However, students did not actively involve in extracurricular activities relating to traffic safety provided in class, mostly because they were not attractive enough.
(iii) The pilot project managed to engage students in traffic safety culture activities (38/38 students answered in questionnaires that they wanted to participate in the activity if the chance arises).
(iv) 33 students said the quiz show was effective.
(v) Most of students think providing TSC toolkits were a good incentive but should be different item for each activity.
(vi) The pilot project contributed to establishing the safe school zone focused on safe-route-to-school program including improved students, teachers and local residents’ awareness (15/15 interviewed teachers, authority staffs, residents and volunteers said implemented safety culture activities were very helpful.).
(vii) TSC student activity corner was successful in improving student’s awareness as most students keep updating the information on traffic safety and talk with one another.
(viii) 36 students affirmed that activity at Ghe intersection have made the significant changes and usefulness and wish to remain continuing the activity.
(ix) Difficulties remaining after the project is the land acquisition of the retail shop that obstructs the pathway to school at Ghe intersection.

8.2 Survey Results from Local Residents and Volunteer Crossing Guards

The questionnaire survey was also conducted with local residents and the volunteer crossing guards. The results show that
(i) Most of residents think traffic signal operation at Ghe intersection was effective while some of them do not think so as it was not fully operated all day long.
(ii) Majority of residents think having traffic safety patrol activity brought about the considerable changes while some of them do not think so as some of the traffic safety patrol volunteers still have negative attitude and impolite.
(iii) There are some difficulties remained. The awareness of local residents is still poor; traffic signal is not operated fully; and students’ home are too far from school and the project limited the area only at Ghe intersection.
(iv) Majority think the pilot project was successful and should be continued.
(v) It was recommended that for the school, there should be more Q&A shows with broader, longer and more frequent activities;
(vi) There should have more enhancements on traffic safety education in schools and communities.
(vii) There should be black spot identification project implementing in schools nationwide.
(viii) There should be the sharing experiences with foreign countries.

8.3 Survey Results from local authorities concerned

Interview survey was conducted with local authorities concerned on opinions towards the overall pilot project and its implementation procedure. The analytical results are made as follows:
(i) The cooperation among relevant agencies as well as their level of interests was inefficient and poor.
(ii) A great advantage was strong desire of local residents, companies, schools in this area to improve current traffic order situation, which remained dangerous and complex situation.
Nevertheless, the obstacle shown that the duration of pilot project was too short implying that such a short-term activity strongly required close cooperation among many concerned organizations.

Moreover, existing technical problems along the NH No.5 involved both central and provincial agencies’ responsibilities which should be taken into consideration for the sake of society as a whole.

8.4 DIFFICULTIES AND LIMITATIONS

Despite the project received the very useful and fruitful results from the surveys, certain numbers of factors had interrupted and slow down the procedure. The success or failure depends deeply upon the enthusiasms line in between the core agencies who wish to make the project realized and the coordinating agencies who wish to make the project possible. It is not a single agency responsible for solving the road traffic safety problem but all agencies, communities and people working together to come up with proper and suitable plan for that particular context. Those difficulties and limitations are:

- **Cooperation among agencies concerned**
  It is apparent that the local authorities from different organizations still have little knowledge of cooperating and working together as a team leading to the delay and uncertainty on whether who should be a focal point to implement the pilot project. The school and people at grass root level, the local residents in particular were willing to learn, cooperate and participate in the activity so long as there was a top-down command while the local authorities were hesitate to involve (even if there was as in line of their responsibility.)

- **Level of communication among agencies concerned**
  Local authorities still rely on a written document/letter for one-way communication (rather than face-to-face communication) leading to delaying the process.

- **Duration of implementation the pilot project and its program**
  The period of conducting a pilot project was too short led to generating less communication among agencies concerned and hurry to wrap up the plan. Period of traffic signal operation at Ghe Intersection was too limited to only a certain given time.

- **Lack of know-how technique and budgetary constraint**
  Local authorities have limited ideas and know-how technique, particularly funding to implement any pilot project leading to unsustainable and inconsecutive project development.

- **The encroachment of retail shops still do exist which obstruct the pathway to the school.**

9. CONCLUSIONS

The pilot project can be concluded as follows:

(i) The implementation of traffic safety culture activity on “Safe-Route-To-School Program” was quite successful in terms of 1) encouraging local participation; 2) raising awareness on traffic safety and 3) promoting traffic safety education and traffic safety culture activity in the school and the local community of Tan Truong Commune, Cam Giang District, Hai Duong Province.
(ii) An introduction of traffic safety culture development through a pilot project activity entails an exercising opportunity for capacity building and human resources development at not only central and local government agencies but also school, community and people at grass root levels.

(iii) An integration of education through traffic safety education information provision and student activity corner programs, engineering through improvement of signage, repaint crosswalk marking, traffic signal operation and enforcement through instruction of traffic laws at both the school and at the Ghe Intersection is a driving force to generate mutual cooperation, communication and participation and working together as a team to accomplish the aim of pilot project.

(iv) The traffic safety culture student activity corner program provided the students enjoyable time and fun, particularly the quiz time and the risk behavior demonstration. This significantly helps implanting traffic safety awareness in students’ mind in a kindhearted manner rather than to force them to learn things without having proper practice before involving in the real motorization world. These indicated that the traffic safety education in curricular shall be accompanied by the practical approach so that the students could have experiences and practices constantly on traffic safety.

(v) The traffic safety patrol program at Ghe Intersection had brought a tremendous change on road users’ attitudes and behaviors despite its short-term activity operation. The students, pedestrians and other road users felt much safer using the road at Ghe intersection when having traffic signal operated and crossing guards assisted crossing the roads.

(vi) The most important finding was that the pilot project helps identifying the key coordinating organizations that play a key role in implementing the traffic safety culture activity in provincial area / school along the national highways is the “Local people committee.” However, this should be working in cooperation and coordination with other local authority and transportation agencies concerned and traffic police in particular so as to succeed implementing the project.”

10. RECOMMENDATIONS

As traffic safety culture is a new concept in Vietnam and may take a long period of time to establish its foundation, it is necessary to equip and prepare the advancement of fundamental knowledge for schools and communities to learn, follow and practice into their daily lifestyle.

In implementation of any traffic safety culture activity, the leaders of Traffic Safety Committees at all levels (province, district and commune) should play key roles. They should have to engage and call for cooperation among all relating sectors, such as Departments of Education and Training (MOET), Public Security (Police agency), Transport (MOT), and other concerned agencies like Culture and Information, Propaganda, under the leadership of local authorities.

Pilot project for traffic safety culture should make positive impacts on 3 areas, including education, enforcement and engineering in target location and make a persuasive encouragement on the community’s participation.
In Cam Giang case, to carry out traffic safety culture activity program for raising awareness and reducing traffic accidents, fully operated traffic signal should be a primary requirement. Apparently, if traffic signals are fully operated 24 hours, this will bring the traffic system formation and pave the way for traffic safety culture establishment.

To make sustainably behavioral change of students and other road users, a constant project activity must be carried out. Hence, the sources of funding are essential at this stage. It is necessary to call for Hai Duong local enterprises’ assistance for financial support to continue carry on the traffic safety culture activities at the school and local residents in Tan Truong Commune, Cam Giang district, Hai Duong province.

The Possibility of continuing/sustaining the project would line on the two significant factors: 1) in terms of budget - The school may ask for sponsorship from the local or foreign companies in the industrial zone in Cam Giang District aside from the government subsidy; 2) in terms of self-conducting the project – The school may require a technical assistance for building capacity of their teachers, students and local residents to think and work out together. Certainly, a strong support from the central and local governments is a must for carry on the project.

The problem on encroachment of retail shops along the pathway to the Cam Giang School is still a controversial issue. This may take a very long period of time for solution. In this case, a land acquisition may be recommended.

The traffic safety culture activity on safe-route-to-school program is actually a part of the safe school zone program which should be introduced to schools nationwide so that all children and students could have an equal chance to feel safer walking or cycling to schools from homes. Therefore, it is recommended that the project should be consecutively carried on under the main theme of the “safe school zone” so as to improve the quality of life and social welfare of all Vietnamese students and citizens for the pursuit of a sustainable development in Vietnam.

REFERENCES


QUANTITATIVE ASSESSMENT OF USED TIRES IMPACT ON ROAD SAFETY IN DEVELOPING COUNTRIES

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Total Equivalent Number of Words: 7463
ABSTRACT

The prevalent use of “used tires” on vehicles mainly in developing countries has been a major source of concern for most transportation agencies in these countries. It is estimated that about two-thirds of tires imported and sold in developing countries are “used tires”. The recent increase of vehicle tire related road incidents such as tire blow-outs have been attributed to the influx of imported “used tires” into these countries for resale to consumers. Although used tires are generally perceived as less safe than new tires, the significantly reduced initial cost is very attractive to consumers. This study attempts to establish the magnitude of the problems, challenges and adverse impacts associated with aged or home used tires in developing countries using Ghana, a developing nation in sub-Saharan West Africa as a case study.

Relevant data for the study included tire importation data and distribution, used tire tread depth and accident data for the past five (5) years on all road links. In addition, a questionnaire survey was conducted throughout the country in order to obtain used tire and road usage information from road users and stakeholders. The data collected was assembled into a comprehensive database and further analyzed using transportation econometric models to identify possible accident correlation to used tire usage in and to provide a quantitative assessment for predicting the likelihood of tire related incidents in Ghana.

The study identified five key factors as having the most influence on the occurrence of tire related road incidents. These include, condition of tire bought (used or new), tire pressure check frequency, tire tread depth or wear check frequency, tire replacement frequency and annual kilometers driven. The study also indicated that the majority of imported used tire tread depths are between 3 mm to 4 mm which increases the risk of road accidents on roadways by approximately 30%. The outcome of this study will assist the transportation agencies in developing countries in their publicity and awareness campaigns aimed at reducing tire related road traffic accidents.

Keywords: Used Tires; Developing Countries; Road Safety; Logit Models; Accident Likelihood;
1.0 INTRODUCTION

The prevalent use of used tires on vehicles mainly in developing countries has been a major source of concern for most transportation agencies in these countries. It is estimated that about two-thirds of tires imported and sold in developing countries are used tires [1]. The high rate of patronage for these tires is primarily due to the fact that consumers generally prioritize the cost of used tires which is considerably lower than new tires over their safety.

In developed countries such as the United States, 400 fatalities, annually, may be attributed to tire failures of all types [2]. Tire failures can be caused by a number of factors such as under- or over-inflation of tires, overloading of vehicles, road hazards, improper maintenance, structural defects, and improper installation in addition to tire aging. It is therefore very complex to estimate, based on crash statistics currently available, how many crashes are caused specifically by tire aging. However, there is no denying the fact that tire aging is a significant factor in tire related road safety. One other commonly held belief is that tire failures are mainly due to poor maintenance. While proper tire maintenance is important for the safe performance of vehicle tires, aging is a phenomenon that is affected by the heat generated in tires and the degradation that occurs due to an oxidation reaction within the rubber components. This is a distinctly different phenomenon from tire inflation and maintenance related issues. Some tire and vehicle manufacturers recommend that consumers replace their tires after a specified number of years, (e.g., 10 years) irrespective of the frequency of use since aging can affect the safe performance of tires even if they have adequate tread and proper inflation.

Tires differ in both new tire performance characteristics and their degradation rates of these performance characteristics during service, making it difficult to predict long-term durability based on testing of a new tire. Also, one challenge associated with assuring long-term durability is in defining the beginning of a tire’s service life, which could be defined as either the date of manufacture as shown in the Tire Identification Number (TIN) on the sidewall of the tire or the date it is placed in service, which could range from weeks to years after the tire is manufactured. Equally challenging is defining the end of a tire’s service life. Traditionally, the end of service life is independent of tire age and defined as the point when the tread wears down to the 1.6 mm (2/32-inch) tread wear indicator bars molded into the tread [2]. However, tires on some vehicles can be in service for many years and yet accumulate very few miles resulting in little or, in the case of spare tires, no tread wear. Thus a tire’s service life is not only determined by chronological age. It is a function of service and storage conditions which is determined by a myriad of factors such as temperature, storage conditions, and conditions of use (e.g., load, speed, inflation pressure, impacts and road hazard damage) to which a tire is subjected throughout its life.

Past research by Bullas (20074) [3] estimate that about 9% of annual road accidents can be attributed to worn tires. The relationship between tread depth and the risk of accidents is by far the most critical factor relevant to this study. A number of research studies have shown that the friction between the vehicle tire and the roadway surface (tire traction) is significantly reduced as the tread depth decreases. Initial studies done by the Transport and Road Research Laboratory (TRRL) [4] indicated that 2.9% of the accidents in the United Kingdom could be attributed to instances of “illegal tread or combinations”. Fox et al. (1979) [5] also revealed that the tire tread depth is a significant factor that contributes to the likelihood of being
involved in an accident with a utility pole. Their study also indicated that the risk increases exponentially when tread depth is less than 3 mm.

The Highway Safety Foundation [6] also conducted a study to determine the relationships between the vehicle tire tread depth and the probability of involvement in a traffic accident. The study aimed at determining objectively the combined effects of tread depth and driver behavior on the relatively high accident rates at lower tread depths. The results of the study indicated an inverse relationship between the occurrence of road accidents and tire tread depth and also recommended a desired legal minimum tread depth of 3.2 mm (4/32 inch). These results validated the findings of the previous study by the Highway Safety Foundation [7]. More recent work conducted by the Finnish Motor Insurers Centre [8] identified that tires with low tread depths had a 9% accidents risk factor in wet conditions, compared to only 1.8% under dry conditions. In addition, research has shown that under normal operating conditions, the hydroplaning speed decreases as the tire tread depth decreases [9]. However, vehicles with low tire tread depths experience poor handling and braking performance long before hydroplaning occurs.

Although most past researchers have identified the contribution of tire tread depth and age to the risk of accidents, there is a general lack of research that quantitatively analyses the direct impact of used tires on the likelihood of accident occurrence especially in developing countries. The broad goal of the study is therefore to establish the magnitude of the problems, challenges and adverse impacts associated with aged or home used tires in developing countries. The outcome of the study will assist the transportation agencies in these countries in their publicity and awareness campaigns aimed at reducing tire related road traffic accidents.

2.0 DATA COLLECTION AND ANALYSIS

For the purposes of this study, a comprehensive database on road safety and tires usage in Ghana was developed. The database was assembled from relevant data sources located in various offices throughout the country. Relevant data for the study included tire importation data and distribution, used tire tread depth and accident data for the past five (5) years on all road links. In addition, a questionnaire survey was conducted throughout the country in order to obtain used tire and road usage information from road users and stakeholders. The data collected was assembled into a comprehensive database and further analyzed for possible accident correlation to used tire usage in Ghana. The following sections describe the data collection and analysis efforts.

2.1 Used Tire Tread Depth Survey

Tire tread depth is one of the most important attributes that indicates wear and tear. Adequate tread depth is paramount to providing sufficient grip and braking resistance in order to avoid collisions. Low tread depth due to wear can cause explosive tire burst resulting in fatal accidents. A used tire tread depth survey was carried out in order to ascertain the tread depths of used tires currently being imported into the country. The survey was carried out at various locations where used tires are imported to be sold to the general public. The locations include second-hand auto stores selling used tires, vulcanizers and isolated used tire sellers in the major cities of Ghana. A total 250 used tires were sampled for their tread depth. The survey indicated that 6% of used tires imported into the country had tread depth less than 2-mm, 15%
had tread depths between 2 to 3-mm, 40% between 3 to 4-mm, 24% between 4 to 5-mm, 11% between 5 to 6-mm and about 4% had tire tread depths greater than 6-mm.

2.2 Questionnaire Survey and Results

The questionnaire survey aimed at soliciting used tire and road usage information from identified tire dealers and distribution points, vehicle operators, transport unions and providers. In order to ensure that the survey sample best represents the majority of the road users in Ghana, the questionnaire survey was carried out in the major commercial centers around the country. Figure 1 below illustrates the breakdown of the survey data obtained at the various locations in the country.

Commercial vehicles such as taxis and para-transit (locally known as trotros) represent the majority of vehicles plying the roadways in the country. As a result, these vehicles will most likely form the majority of vehicles using and frequently changing tires. In addition, private vehicles were also surveyed to obtain their tire maintenance practices, costs and safety considerations in tire purchases and finally an assessment of their knowledge on common tire issues. A total of five hundred (500) questionnaire surveys were undertaken for the purpose of this study. However, six (6) of the survey forms returned were considerably incomplete and therefore excluded from the database thus, resulting in a net total of four hundred and ninety four (494) unique survey data used for the study.
2.3 Tire Maintenance Practices

Regular tire care and maintenance is the key to the well being of vehicle tires and road safety. Monitoring tire wear patterns and tire pressure is crucial for efficient operation of vehicles. Adequate tire pressure prevents excessive uneven wear of the tire that can lead to potential safety problems while excessive tire wear can also provide early indications of suspension and steering component problems, as well as show chronic tire inflation problems. The frequency of tire change by vehicle owners and operators also provides a useful indication about the importance of tire safety to the road user. The survey sought to investigate the frequency of tire pressure and wear check, tire change frequency and the number of tires changed by vehicle owners and operators. Figure 2 illustrates the results and distributions of the various tire maintenance practices amongst the respondents surveyed.

![Figure 2 - Tire Maintenance Practices](image_url)

The above results indicate that majority of the survey respondents (75%) check their tire treads on a weekly basis. This relatively high percentage may be indicative of motorists’ awareness of the importance of tire tread depth to vehicle occupant, driver and pedestrian safety. However, an overwhelming majority (85%) of the respondents only check their vehicle tire pressure when it is low. Only 4% check their vehicle tire pressures every day while 9% check it on a weekly basis. This is indicative of poor tire maintenance practice. The results also showed that 36% of respondents only change their vehicle tires when they encounter problems. Approximately 28% change their tires every 1-2 years while 27% change their vehicle tires in less than 1 year interval. The relatively short tire change duration for these respondent groups may be attributed to used tires which may be close to their useful life span. Finally the results revealed that majority of the survey respondents (40%) typically change two tires at a time.
However, a significant percentage of respondents (28%) change just one tire at a time. This is most likely the defective tire at that particular time due to economic constraints.

### 2.4 Used Tire Costs

The cost of tires is a significant factor that determines the condition of tires (i.e. used or new) that are purchased by consumers. The analysis of the tire cost data obtained from the questionnaire survey indicate that generally the cost of new tires purchased by consumers ranges from GH¢ 100 to GH¢ 250 while that of the used tires ranges from GH¢ 15 to GH¢ 50. On the average, the cost on new tires is typically six (6) times the cost of a used tire. This significantly reduced initial price for used tires is very attractive to budget conscious consumers. Table 1 summarizes the costs of used and new tires as obtained from the questionnaire survey.

#### Table 1 – Tire Costs Comparisons

<table>
<thead>
<tr>
<th>Statistic</th>
<th>New Tire*</th>
<th>Used Tire*</th>
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</thead>
<tbody>
<tr>
<td>Minimum Cost</td>
<td>GH¢ 100.00</td>
<td>GH¢ 15.00</td>
</tr>
<tr>
<td>Maximum Cost</td>
<td>GH¢ 250.00</td>
<td>GH¢ 50.00</td>
</tr>
<tr>
<td>Average Cost</td>
<td>GH¢ 148.52</td>
<td>GH¢ 24.98</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>GH¢ 43.64</td>
<td>GH¢ 7.40</td>
</tr>
</tbody>
</table>

Note: 1 GH¢ = $ 0.96

### 2.5 Tire Costs and Safety Considerations

The two major considerations in purchasing a vehicle tire are cost and safety. Most vehicle owners and operators try to find a balance between these two competing factors during their decision making process. This is evident from the survey results which indicated that 62% of the respondents consider both factors together to make their final purchase decision. The survey also revealed that 31% of respondents consider safety as their primary factor while 3% consider cost as the primary factor. 4% of the respondents did not indicate their tire buying preference which may be due to other factors such as brand loyalty and performance. Figure 3 below illustrates the effects of tire costs and safety on buying considerations.

![Figure 2 – Tire Costs and Safety Considerations](image-url)
The comparative analysis between the condition of tire bought (i.e. used or new) and the factors taken into consideration before buying the tires indicated that the decision to purchase either used or new tires is directly correlated with the two major buying considerations discussed above. The survey revealed that 100% of respondents who considered the tire cost as the main factor before buying a tire bought used tires. This is expected since new tires are significantly more expensive (typically 6 times) than used tires. 54% of respondents, who considered safety as the primary decision factor during tire purchase, bought a new tire as compared to 46% who bought used tires. This result suggests that safety conscious drivers and vehicle owners are more inclined to buy new tires than used tires. This can be attributed to the fact that used tires are more susceptible to have tire problems than new tires. A significant majority of respondents (72%) who considered both safety and cost when making their tire purchase decisions bought used tires. This distribution indicates that although most vehicle owners and operators are aware of the safety implications of used tires, the cost plays a significant factor in their decision.

2.6 Recent Tire Related Incidents

As previously stated approximately 9% of road accidents are a result of tire related problems [Bullas, 2004]. The survey respondents were also asked to indicate the most recent tire problems they have encountered in the past six months. Approximately 41% had encountered no tire related problems within the previous six months; however, about the same percentage had experienced tire wear and tear which is the most common tire related problem. 8% and 5% of the respondents had also experienced puncture or tire blow out respectively whilst driving in the past six months. Within the same period, 5% experienced flat tires while parked. Figure 4 summarizes effect of tire conditions on recent tire related incidents.

The initial condition of tire bought was also found to be highly correlated with the likelihood of having a tire problem within the last six (6) months. The results showed that 80% of respondents who bought used tires experienced a tire blow-out whilst driving as compared to 20% who bought new tires. 62% who bought used tires had flat tires after parking against 19% who bought new tires. For respondents who bought used tires, 100% had punctures whilst driving with none of the new tire buyers having any puncture whilst driving. Similarly, 71% used tire buyers’ experienced significant wear and tear as compared to 30% who bought new tires. The above trends signify that vehicles with used tires are more likely to have tire related problems than vehicles with new tires. This may be due to unforeseen defects in
used tires which becomes apparent once the used tire is placed in service. Finally, the results indicated an almost 50/50 percent split between vehicles with used tires and those fitted with new tires having no tire problems. This can be attributed to the fact that tire problems result from a myriad of factors such as load, speed, under/over inflation, tire tread depth, tire maintenance etc., which are not specific to either used or new tires.

3.0 MODEL DEVELOPMENT

The factors affecting road incidents related to tire problems can be dependent on a variety of factors. These factors can include the tire maintenance practice such as regular tire pressure check, tread wear check, rotation, alignment, balancing and also on the tire replacement frequency, annual kilometer driven and the condition of the tire purchased. In order to capture the likelihood of an occurrence of a tire related road incident, the respondents choices related to “Recent Tire Problems” encountered within the past six (6) months was selected as the response variable. The response variable was transformed into binary variable and coded as 0 for no recent tire related problem and 1 for any of the other tire related incident (Blow-out Whilst driving, Flat tire after parking, Puncture whilst driving and Wear & Tear) indicated on the questionnaire. The choice of “Recent Tire Problems” as the response variable allows for estimation of the effect of various factors on the occurrence of tire related incidents.

3.1 Choice of Model Form

Discrete choice models are frequently-used to develop models of behavioral choice that describes the occurrence or non-occurrence of an event to explicative variables [10]. It is frequently used in survey analysis to model the relationship between a response (dependent) variable and one or more explanatory (independent) variables. The response variable is a discrete variable that represents a choice, or category, from a set of mutually exclusive choices or categories. The observations on the response variable are assumed to have been randomly sampled from the population of interest and generally follow a Bernoulli distribution. The explanatory variables are presumed to affect the choice of the decision maker and represent a prior knowledge about the causal or associative elements important in the choice or classification process. As previously mentioned, for this study, the probability of an occurrence of a tire related safety problem was chosen as the response variable. The most common discrete choice models used to link probability of an event occurrence to the explanatory variables are the Logit Model and Probit Model. The general form of these models are given by

Logit Model:
\[ p = \frac{\exp(\beta_0 + \sum \beta_j X_j)}{1 + \exp(\beta_0 + \sum \beta_j X_j)} \]

Probit Model:
\[ p = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\beta_0 + \sum \beta_j X_j} \exp \left( -\frac{(\beta_0 + \sum \beta_j X_j)^2}{2} \right) dx \]
Where

\[ P = \text{Probability of an event occurrence} \]
\[ \beta_j = \text{model coefficients to be estimated} \]
\[ X_j = \text{Explanatory variables} \]

Although in practice, both the logit model and probit model produce virtually identical results, the logit model is usually preferred, because the mathematical analysis is less complicated and the coefficients are easier to interpret [11]. Consequently, the Logit model was selected as the preferred model form.

### 3.2 Estimation of Logit Model

The model coefficients of the Logit model are estimated using the maximum likelihood estimation (MLE) methods. The maximum likelihood method is a parameter estimation method in which the coefficients of the model are estimated by the values that maximize the likelihood function. The Likelihood function is a probability density function that indicates how likely a particular population is to produce an observed sample. For the Logit model the likelihood function is given by

\[
L(p) = \prod_{i=1}^{n} p^{y_i} (1 - p)^{1-y_i}
\]

And the corresponding log likelihood function is given by

\[
\log(L(\beta)) = \sum_{i=1}^{n} y_i \log(p_i) + \sum_{i=1}^{n} (1 - y_i) \log(1 - p_i)
\]

Where

\[ p = \text{probability of an occurrence of a tire related problem.} \]
\[ y_i = \text{Observed occurrence of tire related problem} \]
\[ \beta_j = \text{Vector of model coefficients (\beta_0, \beta_1, \ldots, \beta_n)} \]

The value of \( \beta_j \) that maximizes the log likelihood function is the estimated coefficient vector \( \beta \) and the estimated value of \( p \) is the probability of an occurrence of a tire related problem within 6 months after the purchase of the tire.

### 3.3 Model Evaluation

Besides selecting an appropriate model form for the analysis, the statistical significance of the estimated regression coefficient for each covariate was investigated. That is, the null hypothesis that a zero coefficient should be rejected if the variable is statistically significant. In addition, the sign and magnitude of each estimated coefficient should be practical and justifiable from an engineering viewpoint. The resulting model yields estimates of the coefficients and standard error for each coefficient from which the p-values and t-statistic can be computed. The t-statistic of the estimated coefficient is the estimated coefficient divided by the estimated standard error. The p-value is the probability that a normal random variable has an absolute value larger than the t-statistic obtained. If the p-value is small, then there is adequate evidence that the corresponding variable is significant, i.e., the difference between the coefficient estimate and zero arises not from chance but from a systematic effect. The model should also
have a reasonable predictive and explanatory ability as indicated by goodness-of-fit measures and statistics. For Logit models, the likelihood ratio test is a common test used to assess two competing models. It provides evidence in support of one model, usually a full or unrestricted model, over another competing model that is restricted (i.e., model having only the constant term). The likelihood ratio test statistic is given by:

$$D_m = -2[\log L(\beta_R) - \log L(\beta_U)]$$

Where

- $\log L(\beta_R)$ = log-likelihood at convergence of the restricted model,
- $\log L(\beta_U)$ = log-likelihood at convergence of the unrestricted model.

The $D_m$ statistic is chi-squared ($\chi^2$) distributed with the degrees of freedom equal to the difference in the numbers of coefficients in the restricted and unrestricted model.

### 3.4 Model Results

The Logit model to predict the occurrence of a tire related problem within six months of purchase was developed in a systematic manner. Each explanatory variable was added in a stepwise manner to test the impact of its inclusion. The variables were added starting from the variable deemed most significant on the basis of the data analysis described in the preceding section. The significance of each explanatory variable was tested using the associated $p$-value: A variable was considered significant if its $p$-value was less than 0.2. The results of the Logit model are presented in Table 2 below.

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
<th>Std error</th>
<th>Chi-Square</th>
<th>p-value</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.965</td>
<td>0.934</td>
<td>4.427</td>
<td>0.035</td>
<td>2.66</td>
</tr>
<tr>
<td>Tire Change Freq</td>
<td>-0.199</td>
<td>0.057</td>
<td>12.322</td>
<td>0.000</td>
<td>-3.22</td>
</tr>
<tr>
<td>Tire Pressure Check Freq</td>
<td>-0.676</td>
<td>0.161</td>
<td>17.726</td>
<td>&lt; 0.0001</td>
<td>-4.26</td>
</tr>
<tr>
<td>Tire Tread Check Freq</td>
<td>-0.782</td>
<td>0.163</td>
<td>22.922</td>
<td>&lt; 0.0001</td>
<td>-4.26</td>
</tr>
<tr>
<td>Annual Kilometers Driven</td>
<td>0.468</td>
<td>0.127</td>
<td>13.675</td>
<td>0.000</td>
<td>3.92</td>
</tr>
<tr>
<td>Condition of Tire</td>
<td>1.065</td>
<td>0.246</td>
<td>18.668</td>
<td>&lt; 0.0001</td>
<td>2.28</td>
</tr>
</tbody>
</table>

Number of States           = 2
Number of observations     = 468
Number of Parameters       = 6
Log likelihood function    = 506.657
Restricted log likelihood  = 628.953
Chi-squared                = 122.295 [< 0.0000]
Pseudo Coefficient of Determination ($\rho^2$) = 0.21
Figure 5 below shows the standardized coefficients (also called beta coefficients) for the Logit Model. Standardization of the model involves transformation of the magnitudes of the variable coefficients into a dimensionless scale. The values of the standardized coefficients indicate the relative weights and importance of the model variables. The higher the standardized value of a coefficient, the more influence the corresponding variable has on the response variable.

Based on the results shown, the probability of occurrence of a tire related road incident is most influenced by the condition of the tire purchased and tire maintenance practices such as tire pressure and tread/wear. In addition, the confidence intervals around the standardized coefficients have values greater than zero (0) which indicates that all the model variables are significant and influence the occurrence of tire related incidents on our roadways.

3.5 Discussion of Model Results

The Logit Model developed for the occurrence of tire related road incidents was found to be the appropriate model for the data obtained from the survey questionnaire. As previously stated all the model variables were found to be highly significant to justify their inclusion in the model. This is evident in the fact that approximately 72% of the survey results were predicted by the model as shown in Table 3 below.

Table 3 – Comparison of Actual and Predicted Results

<table>
<thead>
<tr>
<th>Actual Values</th>
<th>Predicted Values</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>32</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
<td>350</td>
</tr>
</tbody>
</table>
Two other variables, “Number of tires changed at a time” and the “Type of vehicle” were initially included in the model, however they were found to be statistically not significant. From the model results, it can be inferred that good maintenance practices such as regular tire pressure check, tread depth/wear check and tire replacements would significantly reduce the occurrence of tire related road incidents on our roadways. These results are consistent with expectations. As such, vehicle operators should therefore be encouraged to adopt these proactive practices to ensure early detection of tire problems in order to protect the safety of both passengers and drivers.

The model also shows that the condition of tire purchased positively influences the probability of occurrence of tire related incidents on our roadways. That is drivers who purchased used tires have a higher probability of tire related incidents that those who purchased new tires. This result is indicates that the use of used tires on our roadways constitute a safety issue that needs to be addressed through driver education and enforcement of regulations governing the purchase and maintenance of used tires especially on public transportation modes such as taxis, para-transit (trotros) and buses. Other factors such as the annual kilometer driven also contribute significantly to the occurrence to tire related problems on our roadways. This may be attributed to greater exposure of the tire to braking and stopping on the road surface and the adverse elements of the weather which increases the wear and tear of the vehicle tire.

4.0 CONCLUSIONS

Developing countries such as Ghana currently have relatively high road traffic accident rates with one hundred and sixteen (116) fatalities per ten thousand accidents (2007). These accidents can be attributed to myriad of factors. More recently, the issue of vehicle tire related road incidents such as tire blow-outs have been on the increase. Some of these problems have been attributed to the influx of imported “used tires” into the country for resale to consumers. Although used tires are generally perceived as less safe than new tires, the significantly reduced initial cost is very attractive to consumers. Currently, there are no specific regulations for importation of used tires into the country. It is therefore imperative to conduct a study into the impact of used tires and its implications on road accidents in the country in order to make recommendations on the way forward for safe tire use, management and regulations. Based on the study results, the key factors identified as having the most influence on the occurrence of tire related road incidents include:

- Condition of tire bought (Used or New)
- Tire pressure check frequency
- Tire tread depth or wear check frequency
- Tire replacement frequency
- Annual kilometers driven

The study showed that used vehicle tires currently on sale in the country have tread depths ranging from 1.3 mm to 6.7 mm. However majority (62%) have tire tread depths less than 4 mm. Also, 6% of used tires have tread depth less than 2 mm. It should be noted that once a tire has been worn away to this extent, not only will they have radically increased stopping distances and loss of grip. In addition, the internal cords
could become exposed, again potentially leading to dangerous blow outs which can result in fatal road accidents. The study results also revealed that used tires generally cost higher per kilometre travelled and are not always the most economical. In addition, they also increase the occurrence of tire related incidents on our roadways. In contrast, new tires lasts longer, generally cost less per kilometre travelled and result in less road incidents. Although most drivers are aware of the safety impact of used tires, the significantly reduced initial price is very attractive to budget conscious consumers. However, although buying used tire might seem a bargain option for people on a budget; it may not be worth the risk involved.

The study also confirmed that regular tire maintenance practices such as tire pressure check, tire tread depth/wear check and tire replacement beyond the lifespan significantly reduces the occurrence of tire related road incidents on our roadways. It must also be noted that the responses from the survey questionnaire also suggests that about half of drivers are not familiar with the tire information available to consumers on the sidewalls of the tires. For example most of the respondents were not aware that different tires are designed for specific speed limits and also did not know that the recommended tire pressures for a particular vehicle are recommended by the vehicle manufacturer. This lack of information about the associated benefit of regular tire maintenance practice such as improved vehicle fuel efficiency and safer roads among drivers could be a major cause for the poor tire maintenance culture in the country.

5.0 RECOMMENDATIONS

The lack of stringent regulations on importation of used tires has led to their influx in many developing countries. Patronage of these used tires has also enjoyed a steady increase due to budget conscious consumers. However, this study has confirmed that used tires significantly increase the risk of road accidents on our roadway. In order to mitigate the risks involved with used tires usage, the following recommendations should be implemented.

Regular Vehicle Tire Maintenance Education

Early detection of tire problems is paramount in order to reduce the risk of road accidents and to protect the safety of both passengers and drivers. As such, vehicle operators should be encouraged to adopt proactive tire maintenance practices such as regular tire pressure check, tire tread depth/wear check, tire rotation, balancing and alignment. For drivers to adopt a regular tire maintenance culture, the highway safety officials and regulators must embark on a comprehensive public involvement and educational campaign to educate drivers on tire information and the benefits of regular tire maintenance such as improved fuel efficiency and safer roadways.

Road Traffic Regulations & Enforcement

Road traffic regulations in developing countries should be updated to specify a minimum tread depth of 1.6 mm for light vehicles (mini-buses) and heavy vehicles that carry passengers (buses). These vehicle classes experience relatively high road traffic fatalities and represent the second largest category of fatalities (i.e. 23% of the total fatalities) on the roadways [12]. In addition, the vehicle roadworthiness inspections should also include a checklist on vehicle tire condition such that vehicles with tire tread depths less than 1.6 mm should be classified as not road worthy.
**Importation of Used Tires**

The regulatory agencies should strictly inspect all imported used tires and discourage the importation of used tires more than 4 years old. In addition, imported used tires purchased should have at least 3 to 4 mm of tread depth.

**Regular Tire Replacements**

Regular tire replacements beyond the minimum tire tread depth should be enforced since it significantly contributes to a reduction in the occurrence of road accidents. Also, tires should be replaced after 6 years of service regardless of the remaining tread depth. This is due to adverse weather effects that degrades the rubber in tires over time, irrespective of whether the tire is being used or not.

**Wheel Safety Bands**

The tire wheel safety band is an internal rust-free aluminium or alloy steel band fitted to cover the well space on wheels. Once fitted, it creates a solid metal platform, which locks the tire onto the rim and prevents the tire from dislodging and slipping into the wheel well following tire deflation. This allows a driver to run on a flat and maneuver the vehicle with greater control and safety thus protecting the lives and safety of both passengers and driver. In light of these advantages, highway safety officials and regulators should investigate the use of wheel safety bands on all commercial vehicles. These would help mitigate road traffic accidents and fatalities resulting from tire punctures, blow-outs and under inflation.

### 6.0 ACKNOWLEDGEMENTS

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### 7.0 REFERENCES


Contents session 13  Interurban and rural safety, intersections, incident management

Fatality Analysis of Intersection Accidents in Bangladesh
Sabreena Anowar, University of Calgary, Canada

Severity Analysis of Heavy Vehicle Accidents in Bangladesh
Yasmin Shamsunnahar, University of Calgary, Canada

Investigating Driver’s Behaviour Change by Signal Countdown Devices at Intersections in Beijing
Yulong He, Beijing University of Technology, China

Accident characteristics by Road Types on Singapore Roads
Koh Puay Ping, Land Transport Authority, LTA, Singapore

Stopping Propensity at Red Lights in Saudi Arabia
Salaheddine Bendak, Dallah Human Skills Development Company, Saudi Arabia
FATALITY ANALYSIS OF INTERSECTION ACCIDENTS IN BANGLADESH

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ABSTRACT

Intersections are problematic and accident prone locations, especially in developing countries like Bangladesh where the heterogeneity of traffic makes the situation even more complex. In this study, a logistic regression model is applied to a sample of intersection accident data of Bangladesh from 1998 to 2006 to determine the factors contributing to fatality risk. Our results show that there is an increasing trend of fatality risk at intersections in the past nine years. The likelihood of fatality tends to increase when the intersection accident occurs during night time, on an undivided highway, involves single vehicle, non-motorized vehicle, motorized two-wheeler, bus, truck or pedestrian. The fatality risk of an intersection accident also tends to increase when the vehicles are either overloaded or the accident occurs at unlighted intersection at night. On the other hand, an intersection accident is less likely to be fatal when the intersection is attended by a traffic police. Traffic engineers and road safety professionals should target these factors for appropriate remedies on the basis of the aforementioned results. Based on the findings, the research suggests that in addition to the review and subsequent improvement of the existing intersection geometry, public education campaigns and law enforcement strategies are urgently needed to ameliorate the problem.
1 INTRODUCTION

It is an established fact that of all the systems that people have to deal with on a daily basis, road transport is the most complex and potentially the most hazardous. Among the different roadway elements, intersections are recognized as one of the most critical and hazardous locations (Tay and Rifaat, 2007; Ghamdi, 2003). For example, about 43% of all crashes in the United States occur at or near an intersection (Lord et al., 2005) and about 40% of all casualty crashes in Norway occur at junctions (Elvik and Vaa, 2004). Compared to developed countries, the spectrum of intersection crashes, and ensuing deaths and injuries, in the developing countries such as Bangladesh, is very broad and complex. The heterogeneity of traffic, mix of modes with varying speed and maneuvering time on the roadway, makes the traffic and safety situation much more complicated in developing countries.

In Bangladesh, for example, the total reported number of crashes that occurred at the intersections was 4693 (MAAP database) for the years 1998 to 2006. Among them, 51% was fatal, 36% was injurious and the rest were property damage accidents. The crash distribution by type of collision was: rear end (21.7%), head-on (10.5%), sideswipe and 90 degree (13.6%), hit-pedestrian (39%), and other types (15.2%). The statistics clearly demonstrated not only the acuteness and severity of the problem but also the urgent need of research to prevent accidents as well as to reduce their severity.

One way to accomplish such goal is to identify the most probable factors that affect injury severity (Delen, 2006). Keeping that in mind, this research aims to identify the important factors that are significantly associated with the fatality risk in crashes occurring at intersections in Bangladesh.

2 LITERATURE REVIEW

Intersection accidents occur due to failure in the harmonious interaction amongst the basic roadway elements such as road users, the vehicles and the roadway environment. Although extensive literature is available on intersection safety, our survey of the literature did not find many rigorous studies conducted in developing countries and none conducted in Bangladesh.

For ease of understanding, the review is divided into three different parts. The first part covers the studies that applied count data models (Poisson or Negative binomial) to examine the interactions between the different geometric and traffic related elements and accident frequencies. These can be called as the crash frequency studies. The second part comprises of the studies that focused on the outcome of crashes (fatality or injury severity), in order to identify the most likely factors that may be associated with the crash consequence by applying logit or probit models. These can be referred to as the crash severity studies. Lastly, the review focuses on the studies that deals with specific issues, i.e. pedestrian and bicycle safety at intersections, performance evaluation of intersection safety improvement measures or the effect of new types of intersections, e.g. roundabouts etc.

2.1 Crash frequency studies

In an attempt to establish a relationship between accident occurrence and intersection characteristics, several approaches have been used by the road safety researchers. These include multiple linear regression (MLR) models, Poisson regression models and negative binomial (NB) regression models. The inability of the MLR models to adequately describe the non-negative, random and discrete nature of the crash data has been well documented in literature (Chin and Quddus, 2003; Miaou and Lum, 1993). In that case, the Poisson regression model appears to be a natural first choice for modeling such data. However, Poisson model also have its inherent limitation of giving biased estimates in cases with an over-dispersed dataset (Poch and Mannering, 1996; Chin and Quddus, 2003).
To avoid such errors, many researchers (Poch and Mannering, 1996; Kulmala, 1995) employed the NB model instead of Poisson since it relaxed the Poisson requirement that the mean be equal to the variance and could also deal with between-sites variations (Kulmala, 1995). Poch and Mannering (1996) used NB to model the annual frequency of all crashes and three specific types of accidents (rear end, angle and approach-turn accidents) at intersections. Their results showed that an increase in left-turn, right turn and opposing approach volumes, the number of opposing lanes would increase the likelihood of an intersection crash.

Although NB had been widely applied by researchers for crash frequency modeling, it failed to take into account location-specific effects and/or serial correlation in time of the accident counts. To overcome this problem, Shankar et al., 1998 suggested the use of the random effect negative binomial model (RENB). Chin et al.(2003) applied random effect negative binomial model (RENB) to identify the geometric elements, traffic factors and traffic control measures that may influence traffic safety at intersections. Among the 32 possible explanatory variables considered, total approach volumes, the numbers of phases per cycle, uncontrolled left-turn lane and the presence of a surveillance camera were found as the most significant ones.

Yan et al. (2005) applied the quasi-induced exposure concept and logistic regression methods to explore the overall characteristics of rear-end accidents at intersections as well as to investigate the accident propensity for different vehicle roles (striking or struck) at signalized intersections. Their results showed that number of lanes, divided/undivided highway, accident time, road surface condition, highway character, urban/rural, and speed limit, vehicle type and four factors related to driver characteristics including driver age, alcohol/drug use, driver residence, and gender had significant associations with the risk of rear-end accidents.

Kulmala (1994) studied the effects of road measures implemented at main intersections using a before-after study. Amongst the measures that were tested for effectiveness, road lighting, stop signs, signal control, and lowering of the speed limit value were found to decrease the number of accidents. However, through-flow junction widening, additional lanes for turning vehicles, and road widening did not seem to affect the safety at junctions to any marked extent.

Several other studies have also examined the impact of traffic and geometric characteristics on the frequency of crashes at intersections including lane arrangement (Wang and Abdel-Aty, 2006), signal timing (Wang and Abdel-Aty, 2006; Bonneson and Zimmerman, 2006), curvature (Savolainen and Tarko, 2005) and collision type (Abdel-Aty et al., 2005; Jagannathan et al., 2006) using a variety of crash frequency models.

2.2 Crash severity studies
Intersections are a common place for crashes. And these crashes usually tend to be very severe in nature. For instance, in United States, intersection crashes account for nearly half of all fatal and injury crashes (Isebrands, 2009). This might be due to the fact that the most injurious crashes such as angle and left turn collisions commonly occur at intersections. Therefore, there is a need to identify the effects that vehicle, driver and roadway/environment characteristics have on the injury level of such crashes. Researchers have employed many statistical techniques to analyze intersection accident injury severity. These techniques range from simple cross tabulation/frequency analysis to binary logistic, multinomial logit, nested logit, and ordered logit and probit models.

Al-Ghamdi (2002) examined the characteristics of urban accidents by location (intersection and non-intersection) using the contingency table analyses or $\chi^2$-tests. The study found that improper driving behavior, more specifically running red light and failing to yield, was the primary cause of accidents at signalized urban intersections in Riyadh.
Abdel-Aty and Keller (2005) applied the ordered probit model to explore the severity levels of crashes at signalized intersections. Their results showed that having a divided minor roadway or a higher speed limit on the minor roadway decreased the level of injury while crashes involving a pedestrian/bicyclist and left turn crashes had the highest probability of a more severe crash.

Tay and Rifaat (2007) conducted a similar study using intersection crash data from Singapore. Their results revealed that vehicle type, road type, collision type, driver’s characteristics and the time of day were important determinants of the severity of crashes occurring at intersections.

In another study, Abdel-Aty (2003) analyzed the injury severity levels of drivers’ involved in two vehicle traffic crashes at signalized intersections. In the ordered probit model estimated, driver age and gender, vehicle type, not wearing a seat belt, point of impact and area type were found as significant factors affecting driver’s injury severity. Driver’s violation was also significant but with a negative impact on the injury severity. The author also applied multinomial logit and nested logit models for explaining the same variables. After comparing the outcomes of all the models, the author suggested that ordered probit approach could easily be applied and was best suited for such analysis.

2.3 Other studies

Among the different types of collisions occurring at any signalized intersection, multivehicle rear end collisions are the most prevalent. Therefore, this particular collision type has received the attention of many researchers. For example, Khattak (2001) used real-life data to analyze the effect of information and vehicle technology on injury severity in rear-end crashes, while controlling for the effects of driver, vehicle, and roadway factors. The author found that in the event of two vehicle crashes, the leading driver was more severely injured whereas, in case of three vehicle crashes, the driver in the middle vehicle was more severely injured. The injury severity model also showed that being in a newer vehicle had a negative impact on the driver injury level for both the striking and struck roles.

Das et al. (2008) simultaneously examined the crash characteristics that explain the location (intersection crashes versus segment crashes) and the severity of crashes. The analysis was carried out by simultaneous estimation of models for crash location and injury severity at five values of intersection influence areas. The model for crash location variable indicated that, during peak hours, crashes were less likely to occur at or in the vicinity of intersections. It was also found that an increase in the pavement surface width and speed limits combined with lower Average Annual Daily Traffic (AADT) increased the severity of the crashes.

Yan and Radwan, (2007) explored the relative crash risk for unprotected left-turn accidents frequently occurring at signalized intersections whereas Roudsari et al. (2007) concentrated on the injury severity of the occupants during a left turn movement. Roudsari et al. (2006) compared the odds ratio of severe injuries and crash fatality rate for right- and left-turn collisions at intersection with that of the straight vehicle movement. The study by Lee et al. (2005) identified the group of drivers and pedestrians, and traffic and environmental characteristics that were correlated with high pedestrian crashes using log-linear models. It also estimated the likelihood of pedestrian injury severity when pedestrians were involved in crashes using an ordered probit model.

Steinman and Hines (2004) also assessed safety at signalized intersections for pedestrians and bicyclists. They rated six intersection characteristics and found that a protected left-turn phase with a pedestrian phase increased safety, as did a smaller intersection radius and prohibited right turns on red. Additionally, a lower speed limit was found to make crossing conditions safer for pedestrians and bicyclists.
The traffic safety effects of roundabouts have also been the topic of several interesting studies for the last decades. Antov et al., (2009) found that the main factor influencing the drivers’ speed choice was an inscribed circle diameter of the roundabout. Daniels et al. (2009) applied Poisson and gamma modeling techniques for exploring the reasons behind variance in safety performance of roundabouts using the crash, traffic and geometric data of a sample of 90 roundabouts in Flanders-Belgium. The results showed that the variation in crash rates was relatively small and mainly driven by the traffic exposure.

3 STUDY OBJECTIVE
Our literature review found little research that focus on identifying the factors determining the fatality risk of intersection crashes in Bangladesh or other developing countries even though intersection crashes constitute a significant share of the crashes resulting in fatalities. Therefore, this study aims to identify the factors that contribute to the fatality risk of intersection crashes in Bangladesh to provide transportation engineers and other road safety professionals with some useful insights to reduce the severity of such crashes.

4 DATA
In Bangladesh, the police service is the core organization that is responsible for road accident data collection and storage. Under the current operating framework, police does the investigation and reporting of accidents. They are provided with an investigation form and some training on its use. They are also responsible for the transcription of data into the Micro Computer Accident Analysis Package (MAAP5) software. It should be noted here that the Transport Research Laboratory (TRL) of the United Kingdom developed the MAAP computer software package specifically for storage and analysis of road accident data.

For each accident, a sub-inspector of the police service completes the traffic accident report form after visiting the crash site. The Accident Report Form (ARF) is then dispatched to the respective Accident Data Units (ADU) where the information from ARF and location of the accident are entered into MAAP. Dhaka Metropolitan is one of the ten ADU’s established for data processing.

The Accident Research Institute (ARI) at Bangladesh University of Engineering and Technology (BUET) has access and usage of the MAAP database. This database is transferred to ARI with institutional collaboration of the Road Safety Cell (RSC) of the Bangladesh Road Transport Authority (BRTA) and the Police Department. The current road safety research and investigation work is based on this database.

Like all accident database, the accident data reporting system in Bangladesh also has some underreporting problem. Nevertheless, it is still the more comprehensive and reliable database available in the country. Since the MAAP data has now been included as part of the official First Information Report (FIR) form, it is expected that the reliability of system will continue to improve in future years.

Data on traffic accidents for the last nine years (January 1998 to December 2006) that occurred at intersections in Bangladesh were extracted from the accident records database maintained at the ARI. The data included accident date, time, location and other relevant information. For the analysis, the dataset was divided into two parts, i.e. the fatal accidents and the non-fatal accidents (including grievous injury, simple injury and property damage only accidents). Of the 4693 accidents, 51% was recorded as fatal and 49% was recorded as non fatal.
5 EMPIRICAL MODEL

5.1 Statistical method
The binary logistic regression belongs to the group of regression methods for describing the relationship between explanatory variables and a discrete response variable. It is developed to predict a binary dependent variable as a function of predictor variables. The binary logistic regression has often been used to assess risk factors for various diseases, and in recent years, it has been used in transportation and safety studies where the dependent variable is binary (Al-Ghamdi, 2002, Abdel-Aty et al., 2004 and Drummer et al., 2004). Since the dependent variable in the present study is binary in nature, the binary logistic regression model is an appropriate method of analysis.

In this study, the logit is defined as the natural logarithm of the odds or the likelihood ratio of the dependent variable being equal 1 (fatal) as opposed to 0 (non-fatal). The probability \( P \) of a fatal crash is given by:

\[
\logit(P) = \ln \left( \frac{P}{1-P} \right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \epsilon_i
\]

where \( Y \) is a latent variable measuring injury severity (fatal or non-fatal)
\( x_1, x_2, \ldots, x_n \) are explanatory variables
\( \beta_1, \beta_2, \ldots, \beta_n \) are unknown parameters
\( \epsilon_i \) is the error term with extreme value type I distribution

The conditional probability of a positive outcome is determined by:

\[
\pi(x) = \frac{\exp(\beta x)}{1 + \exp(\beta x)}
\]

The likelihood function can then be expressed as follows:

\[
l(\beta) = \prod_{i=1}^{n} \pi(x_i)^{y_i} (1 - \pi(x_i))^{1-y_i}
\]

where \( y_i \) denotes the \( i \)th observed outcome, with the value of either 0 or 1 only, and \( n \) is the number of observations.

The best estimate of \( \beta \) could be obtained by maximizing the log likelihood function:

\[
LL(\beta) = \ln(l(\beta)) = \sum_{i=1}^{n} \left[ y_i \ln(\pi(x_i)) + (1 - y_i) \ln(1 - \pi(x_i)) \right]
\]

The STATA program, LOGIT, was used for model development and the hypothesis testing was based on 5% significant level.

5.2 Description of variables in model
In developing the statistical model used in this study to identify the factors affecting fatality risks of the crashes at intersections, the characteristics of the intersections, vehicle attributes, crash characteristics, roadway features, time of crashes and weather and roadway conditions are considered. Based on the findings from previous studies and the availability of data as well as considering the local attributes, 19 factors that might have an association with the fatality risk at intersections were selected for investigation. Each variable was tested for statistical significance and the insignificant ones were eliminated one by one. In the final model, 12 factors were retained. A summary statistics of the variables used in the study was presented in Table 1.
Table 1: Descriptive statistics of variables

<table>
<thead>
<tr>
<th>Variables (Description)</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Trend</strong> (1 = 1998 to 9 = 2006)</td>
<td>4.48</td>
<td>2.59</td>
</tr>
<tr>
<td><strong>Time of Day</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Period (1=Peak Period; 0=Otherwise)</td>
<td>0.36</td>
<td>0.48</td>
</tr>
<tr>
<td>Off-peak Period (1=Off-peak Period; 0=Otherwise)</td>
<td>0.32</td>
<td>0.46</td>
</tr>
<tr>
<td>Night-time (1=Night-time; 0=Otherwise)</td>
<td>0.31</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Number of Vehicles Involved</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Vehicle (1=Single vehicle; 0=Otherwise)</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Two Vehicles (1=Two Vehicles; 0=Otherwise)</td>
<td>0.48</td>
<td>0.49</td>
</tr>
<tr>
<td>Three or More Vehicles (1=Three or More Vehicles; 0= Otherwise)</td>
<td>0.01</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Types of Roadway Section</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross Intersection (1=Cross Intersection; 0=Otherwise)</td>
<td>0.30</td>
<td>0.46</td>
</tr>
<tr>
<td>T-Intersection (1=T-Intersection; 0=Otherwise)</td>
<td>0.51</td>
<td>0.49</td>
</tr>
<tr>
<td>Staggered Intersection (1=Staggered Intersection; 0=Otherwise)</td>
<td>0.06</td>
<td>0.23</td>
</tr>
<tr>
<td>Roundabout (1=Roundabout; 0=Otherwise)</td>
<td>0.09</td>
<td>0.30</td>
</tr>
<tr>
<td>Other Intersections (1=Other Intersections; 0=Otherwise)</td>
<td>0.02</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Traffic Control &amp; Operations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unsignalized (1=Unsignalized; 0=Otherwise)</td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td>Police-control (1=Police-controlled; 0=Otherwise)</td>
<td>0.18</td>
<td>0.39</td>
</tr>
<tr>
<td>Signalized (1=Signalized; 0=Otherwise)</td>
<td>0.02</td>
<td>0.14</td>
</tr>
<tr>
<td>Signalized + Police (1=Signalized + Police; 0=Otherwise)</td>
<td>0.25</td>
<td>0.43</td>
</tr>
<tr>
<td>Other Control (1=Other Control; 0=Otherwise)</td>
<td>0.10</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Types of Collisions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head-on (1=Head-on; 0=Otherwise)</td>
<td>0.10</td>
<td>0.30</td>
</tr>
<tr>
<td>Rear-End (1=Rear-End; 0=Otherwise)</td>
<td>0.22</td>
<td>0.41</td>
</tr>
<tr>
<td>Right-angle (1=Right-angle; 0=Otherwise)</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>Side-swipe (1=Side-swipe; 0=Otherwise)</td>
<td>0.09</td>
<td>0.29</td>
</tr>
<tr>
<td>Overturn (1=Overturn; 0=Otherwise)</td>
<td>0.03</td>
<td>0.19</td>
</tr>
<tr>
<td>Hit-pedestrian (1=Hit-pedestrian; 0=Otherwise)</td>
<td>0.39</td>
<td>0.49</td>
</tr>
<tr>
<td>Other Collision (1=Other Collision; 0=Otherwise)</td>
<td>0.09</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Presence of Median</strong> (1=Divider; 0=Otherwise)</td>
<td>0.45</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Weather Condition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fair (1=Fair; 0=Otherwise)</td>
<td>0.96</td>
<td>0.19</td>
</tr>
<tr>
<td>Rain/Wind (1=Rain/Wind; 0=Otherwise)</td>
<td>0.03</td>
<td>0.16</td>
</tr>
<tr>
<td>Fog (1=Fog; 0=Otherwise)</td>
<td>0.01</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Road Class</strong> (1=National; 0=Otherwise)</td>
<td>0.23</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Road Environment</strong> (1=Urban; 0=Otherwise)</td>
<td>0.68</td>
<td>0.47</td>
</tr>
<tr>
<td><strong>Types of Vehicles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMV (1=NMV; 0=Otherwise)</td>
<td>0.01</td>
<td>0.09</td>
</tr>
<tr>
<td>M2W (1=M2W; 0=Otherwise)</td>
<td>0.03</td>
<td>0.16</td>
</tr>
<tr>
<td>M3W (1=M3W; 0=Otherwise)</td>
<td>0.07</td>
<td>0.26</td>
</tr>
<tr>
<td>Bus (1=Bus; 0=Otherwise)</td>
<td>0.39</td>
<td>0.49</td>
</tr>
<tr>
<td>LV (1=LV; 0=Otherwise)</td>
<td>0.14</td>
<td>0.35</td>
</tr>
<tr>
<td>Truck (1=Truck; 0=Otherwise)</td>
<td>0.29</td>
<td>0.45</td>
</tr>
</tbody>
</table>
Other Vehicles (1= Other Vehicles; 0=Otherwise) 0.05 0.21
Vehicle Loading (1=Legal; 0=Otherwise) 0.79 0.40

Note: NMV=Non-motorized transport; M2W=Motorized two wheelers; M3W=Motorized three wheelers; LV=Light Vehicles

Although most of the factors and variables are self-explanatory, two require further clarifications. First, the time of day is divided into the three typical periods. The peak hours consist of the morning peak period between 9:00 am to 12:00 pm, and the afternoon peak period between 3:00 pm to 6:00 pm. The daytime off-peak hours comprise the morning off-peak period between 6:00 am to 9:00 am, and the afternoon off-peak period between 12:00 pm to 3:00 pm while night time is defined as the hours between 6:00 pm and 6:00 am. Second, vehicles involved in crashes are classified into several convenient categories based on the attributes and classification by Bangladesh Road Transport Authority (BRTA). Buses include buses and minibuses; trucks include heavy trucks and lorries engaged in transporting heavy goods; light vehicles comprise of car, jeep and pick up vans. Auto-rickshaws and temps are categorized into one category in motorized three wheelers (M3W). Motorized two wheeler (M2W) comprises of motor cycles while non-motorized vehicle (NMV) includes rickshaw, bi-cycles and push-carts. The rest of the vehicles are categorized as others.

6 DATA ANALYSIS AND RESULTS
The estimation results consisting of the final set of variables, their coefficients together with the P-values for the logistic regression model are reported in Table 2. Since most of the factors were characterized by a series of dichotomous variables, one of the variables must be used as a reference in the estimation. From the calibrated model, the effects of the identified factors on intersection crashes were studied by examining the coefficient values of the variables against the reference case. For example, for the time of day effect, the reference case used was peak-period and the estimate for the night-time and off-peak period variables therefore yielded the effect of night-time and off-peak hour on intersection crash fatality risk relative to peak-hour.

It should be noted that some of the variables are not significant but are retained in the model as long as at least one of the variables for the factor is statistically significant. As suggested by some researchers (Kockelman et al., 2002; Tay and Rifaat, 2007), variables with low statistical significance may also be retained in the model if they belong to factors that have some significant effect on injury severity. Although this approach may reduce the efficiency of the estimates, it is adopted for ease of comparison and interpretation of the estimates. This potential decrease in efficiency has been adjusted by using a more liberal confidence level of 90% instead of the traditional 95%.

The positive co-efficient of the time trend implies that the fatality risk at the intersections has been increasing with time. The finding is supported by the reported accident statistics of the BRTA. The number of both motorized and non-motorized vehicles has increased drastically over the past few years in Bangladesh. The mix of NMV’s and MV’s at the intersections has made the already confusing intersection maneuvers more complex. This may result in increased fatality in crashes as indicated by the result. Apart from the heterogeneous mix of vehicles, the disproportionate increase in traffic volume may also contribute to the high probability of fatality in intersection crashes. Several studies (Chin et al., 2003; Kulmala, 1995; Abdel-Aty et al., 2000; Poch et al., 1996) have indicated that traffic volume increases accident occurrence.
Table 2: Parameter estimation of the fatality risk model

<table>
<thead>
<tr>
<th>Logistic Regression</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Trend</strong></td>
<td>0.092</td>
<td>0.014</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Time of Day (Reference: Peak Period)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off peak period</td>
<td>0.123</td>
<td>0.083</td>
<td>0.139</td>
</tr>
<tr>
<td>Night time</td>
<td>0.151</td>
<td>0.087</td>
<td>0.082</td>
</tr>
<tr>
<td><strong>No of Vehicles Involved (Reference: Two Vehicles)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single vehicle</td>
<td>0.709</td>
<td>0.140</td>
<td>0.000</td>
</tr>
<tr>
<td>Three or more vehicles</td>
<td>0.548</td>
<td>0.313</td>
<td>0.080</td>
</tr>
<tr>
<td><strong>Types of Roadway Section (Reference: Other Junctions)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross junction</td>
<td>0.747</td>
<td>0.267</td>
<td>0.005</td>
</tr>
<tr>
<td>T-junction</td>
<td>0.632</td>
<td>0.262</td>
<td>0.016</td>
</tr>
<tr>
<td>Staggered junction</td>
<td>0.531</td>
<td>0.295</td>
<td>0.072</td>
</tr>
<tr>
<td>Roundabout</td>
<td>0.635</td>
<td>0.284</td>
<td>0.025</td>
</tr>
<tr>
<td><strong>Traffic Control &amp; Operations (Reference: Uncontrolled Intersection)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Police control</td>
<td>-0.665</td>
<td>0.107</td>
<td>0.000</td>
</tr>
<tr>
<td>Signalized</td>
<td>-0.132</td>
<td>0.233</td>
<td>0.570</td>
</tr>
<tr>
<td>Police + signalized</td>
<td>-0.947</td>
<td>0.112</td>
<td>0.000</td>
</tr>
<tr>
<td>Other controls</td>
<td>-0.172</td>
<td>0.121</td>
<td>0.155</td>
</tr>
<tr>
<td><strong>Types of Collisions (Reference: Rear-End)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head-on</td>
<td>-0.180</td>
<td>0.129</td>
<td>0.166</td>
</tr>
<tr>
<td>Right angle</td>
<td>-0.102</td>
<td>0.165</td>
<td>0.537</td>
</tr>
<tr>
<td>Sideswipe</td>
<td>-0.345</td>
<td>0.135</td>
<td>0.011</td>
</tr>
<tr>
<td>Overturn</td>
<td>0.041</td>
<td>0.232</td>
<td>0.859</td>
</tr>
<tr>
<td>Hit-pedestrian</td>
<td>0.874</td>
<td>0.159</td>
<td>0.000</td>
</tr>
<tr>
<td>Other collisions</td>
<td>-0.534</td>
<td>0.156</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Presence of Median (Divider)</strong></td>
<td>-0.352</td>
<td>0.090</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Weather Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rain/wind</td>
<td>0.102</td>
<td>0.209</td>
<td>0.626</td>
</tr>
<tr>
<td>Fog</td>
<td>0.825</td>
<td>0.399</td>
<td>0.039</td>
</tr>
<tr>
<td><strong>Road Class (National Highways)</strong></td>
<td>0.386</td>
<td>0.094</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Road Environment (Urban)</strong></td>
<td>-0.708</td>
<td>0.100</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Types of Vehicles (Reference: Light Vehicles)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NMV</td>
<td>1.328</td>
<td>0.403</td>
<td>0.001</td>
</tr>
<tr>
<td>M2W</td>
<td>0.556</td>
<td>0.233</td>
<td>0.017</td>
</tr>
<tr>
<td>M3W</td>
<td>0.079</td>
<td>0.156</td>
<td>0.610</td>
</tr>
<tr>
<td>Bus</td>
<td>0.679</td>
<td>0.105</td>
<td>0.000</td>
</tr>
<tr>
<td>Truck</td>
<td>0.776</td>
<td>0.110</td>
<td>0.000</td>
</tr>
<tr>
<td>Other vehicles</td>
<td>1.141</td>
<td>0.190</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Loading Condition (Legally Loaded)</strong></td>
<td>-0.291</td>
<td>0.090</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Number of Observations: 4693
Log likelihood = -2526.195
Chi-square = 1452.23
P-value < 0.0001
Pseudo-R-Square = 0.2233
Our results showed that compared to the peak hour crashes (9AM-12PM and 3PM-6PM), night time crashes at intersections were more likely to be fatal. During night-time, many vehicles tended to speed as there would be fewer vehicles on road, despite having less visibility. Various studies reinforced this finding (Tay et al., 2007; Abdel-Aty, 2003). In addition, late night drowsiness of the drivers might also be another factor associated with an increase in the fatality risk.

The number of vehicles involved in an intersection crash was found to have significant effect on the fatality risk. Compared to two vehicle crashes, single vehicle and multiple vehicle intersection crashes had a higher probability of being fatal. Most of the single vehicle crashes in Bangladesh involved hitting pedestrians. These crashes were expected to be more fatal as these involved the unprotected vulnerable road users (Barua et al., 2007).

Junction type was also found to have a significant effect on the fatality risk of intersection crashes. Fatality risk of the cross junctions were found to be more than that of the T-junctions, staggered junctions and roundabouts. Studies had found cross junctions to be more hazardous than other types of junctions as these have more approaching lanes leading to higher likelihood of side-impact crashes (Tay et al., 2007; Elvik et al., 2004).

Modern roundabouts are considered as an innovative design element that can significantly improve intersection safety (Elvik, 2003; Flannery, 2001; Persaud et al., 2001). With respect to traffic safety, a roundabout has been proven to reduce the number of crashes with injuries or fatalities (Elvik, 2003; Persaud et al., 2001). But this study found a contradicting result. Our result might be attributed to the inappropriate geometric design of roundabouts coupled with the absence of proper complementary facilities for pedestrians, lack of appropriate signage and markings and not to mention the motley of vehicle fleet comprising of motorized and non-motorized modes. Moreover, many drivers were not very familiar with the priority rules to be followed for proper and safe functioning of roundabouts.

Our analysis also showed that fatality risk of crashes would be reduced if the junctions were either fully police regulated or signalized with police presence. This result was expected as enforcement measures, particularly the presence of traffic police, often slowed down vehicles at intersection approaches which might reduce the severity of crashes. In addition, police presence also compelled drivers to obey the traffic rules and follow the signals which helped to reduce both vehicle-vehicle and vehicle-pedestrian conflicts in intersections. Sisiopiku et al. (1999) reported the effectiveness of stationary police control on the reduction of vehicular speed.

If the approach roads of the intersections had dividers, then it resulted in lower fatality risk in a crash. In addition to separating the opposing traffic, the dividers reduced the approach speed of vehicles as well as preventing head-on collisions, thus lowering crash severity. It also imposed some restrictions on the turning movements of vehicles at intersections and thus reduced conflicts (Elvik et al., 2004).

In comparison with the rear end crashes, sideswipe collisions were associated with lower fatality risk whereas hit-pedestrian collisions significantly increased the fatality risk of intersection crashes. Interestingly, in contrast to findings from developed countries (Tay et al., 2007; Obeng, 2009), head-on and side impact collisions did not have significant effect on the fatality risks. Again, this difference in findings might be attributed to the drastically different mix of road users and speed of traffic. In congested low speed environment, head-on and side-impact collisions were not only less frequent but also less severe. Hit-pedestrian crashes were more likely to be fatal as these involved the unprotected road users. Moreover, drivers in countries like Bangladesh had little or no regard for pedestrians.

Our study found that the fatality risk of intersection crashes increased if the weather is foggy. Drivers’ visibility would be reduced significantly in the foggy weather making them less efficient in their stopping maneuvers. In a study of relationship between road accident
severity and recorded weather in England and Wales, Edwards (1998) found that fog resulted in higher accident severity. The intersections on National Highways bore higher fatality risk than the intersections on Regional and Feeder Routes. Since the National Highways in our study were mostly located in rural areas, the reduced fatality risk of the urban intersections complemented this finding. Rural crash victims might not have the same access to emergency and medical facilities as their urban counterparts. Motor vehicle injury fatality rates had consistently been reported to be higher in rural areas than in urban areas by several studies (Zwerling et al., 2005; Muelleman et al., 1996).

With regards to the vehicle type, our results showed that compared to the light vehicles, the fatality risks of NMV, M2W, bus and truck were higher in an intersection crash. Clearly, the occupants of both the NMV’s and M2W’s were the most vulnerable ones as they would have minimal protection against crash injuries. The difference in vehicle sizes and masses also made the two-wheelers subject to greater impact forces in any collision resulting in higher fatality risk. The increased fatality risk of buses might be explained by their high occupancy. Obeng (2009) reported that the probability of the occupants sustaining injuries increased with the increase in their numbers. Compared to the overloaded vehicles, the fatality risk of intersection crashes reduced substantially for the vehicles whose loads were within the legal limits. Intersection maneuvers that involved turning movements would become difficult when the vehicle was overloaded. As a result, these vehicles might overturn and become involved in a fatal intersection crash.

7 CONCLUSIONS AND RECOMMENDATIONS
In an attempt to identify some of the significant explanatory variables which may be associated with intersection crash fatality, a logistic regression model is applied to a sample of intersection accident data from Bangladesh the years 1998 to 2006. Our results show that there is an increasing trend in the fatality risk at intersections over the past nine years. The likelihood of fatality tends to increase when the intersection accident occurs during night time, on an undivided highway, involve single vehicle, NMV, M2W, bus, truck or pedestrian. The fatality risk of an intersection accident also tends to increase when the vehicles are either overloaded or the accident occurs at unlighted intersection in the dark. On the other hand, an intersection accident is less likely to be fatal when the intersection is signalized and attended by a traffic police.

Based on these findings, we suggest that in addition to conducting a safety review and subsequent improvement of the existing intersection geometry, public education campaigns and law enforcement strategies are urgently needed to ameliorate the problems. Since non-motorized vehicle riders find it very difficult to make turns at intersections without coming into conflict with motor vehicles, intersections should be designed with provisions to segregate non-motorized vehicle traffic. Other safety improvements that we suggest include building sidewalks where traffic volumes are high, installing pedestrian signals at intersections, and erecting solid medians at intersection approaches. The intersections should be well lit and more conspicuous and reflective signs should be appropriately placed to warn the drivers in advance. Also the placement of objects and signboards impeding the sight distance should be prohibited.

8 ACKNOWLEDGEMENTS
The authors would like to extend their sincere appreciation to the Accident Research Institute (ARI) at the Bangladesh University of Engineering and Technology (BUET) for providing the data used in this study.
REFERENCES


SEVERITY ANALYSIS OF HEAVY VEHICLE ACCIDENTS IN BANGLADESH

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ABSTRACT
Heavy vehicle accidents constitute a significant proportion of total accidents in Bangladesh every year. Heavy vehicles were involved in more than twenty thousand accidents between the years 1998 and 2006 of which more than sixty five percent were fatal accidents. However, very few studies have examined the factors contributing to the number or severity of accidents involving heavy vehicles. This study attempts to identify the factors that affect the severity of heavy vehicle accidents in Bangladesh. A multinomial logit model is applied to a sample of heavy vehicle accident data from 1998 to 2006. The model results show that severity of heavy vehicle accidents increases when there is either a head-on collision, hit-pedestrian or single vehicle collision. On the other hand, presence of police and speed-hump significantly reduces the likelihood of severe heavy vehicle accidents. A heavy vehicle accident tends to be less severe when the accident occurs on culverts or involve young driver. A comprehensive and balanced implementation of engineering strategies, education policies and enforcement tactics targeting these significant factors should be considered to mitigate severe heavy vehicle accidents and thus enhance heavy vehicle safety.
1 INTRODUCTION
Road traffic accidents and injuries are a global health problem and developing countries such as Bangladesh are the most burdened. Over the last few decades, although the incidence of traffic crash fatalities and injuries has been reduced significantly in high income countries, traffic safety problems have become more acute in the developing world. If proper actions are not taken soon, the World Health Organization (WHO) estimate of 1.2 million road traffic deaths and 50 million injuries are forecasted to rise by some 65% globally and 80% for the low and middle income countries between 2000 and 2020.

Traffic safety statistics in Bangladesh and other developing countries had identified trucks and buses as major contributors to road accidents. In Bangladesh, these heavy vehicles were involved in more than twenty thousand accidents between the years 1998 and 2006, of which more than sixty five percent were fatal accidents. The high likelihood of fatality in accidents involving heavy vehicles clearly demonstrated the need for a comprehensive and in-depth study on heavy vehicle accidents to understand the factors associated with the crash outcomes. Therefore, this research aimed to identify the factors determining injury outcomes associated with heavy vehicle crashes using a multinomial logit model. Based on the findings, targeted prevention strategies and potential safety countermeasures would be developed to improve the grim road safety situation in Bangladesh.

2 LITERATURE REVIEW
Although extensive literature is available on heavy vehicle (bus, truck) crash injury severity and its associated factors, our survey of the literature did not find many rigorous studies or statistical analysis of the factors contributing to the either the frequency or severity of accidents in the developing countries.

In the study of passenger car accidents in Sweden, Björnstig et al. (2008) identified heavy vehicles, mostly trucks, as the collision objects in half of all multi-vehicle collision resulting in the deaths of passenger car occupants. Their study recommended median barrier installation, building less injurious fronts on trucks and buses, improving skid prevention, and use of flexible speed limits that vary with road and light conditions in order to reduce the risks of fatal collisions.

In another, Montufar (2002) used Geographic Information System (GIS) to analyse and evaluate heavy truck safety in Canada. The study used a database that integrated truck flows, pavement conditions, geometric characteristics of highway, truck size and weight regulation, and crash information to identify the spatial and temporal characteristics of truck collisions. The study identified adverse weather condition, undivided highways and intersections as the influencing factors of heavy truck collisions.

In order to identify the specific characteristics of truck accidents in America, Joshua and Garber (1990) developed a mathematical relationship to predict the expected number of large truck accidents during a year at a given segment of highway, from a given set of independent traffic and geometric variables. Their estimations revealed that the slope change rate, the average daily traffic, the percent of trucks and the difference in speed between trucks and non-trucks influenced the number of truck involved accidents at a given stretch of highway.

Daniel et al. (2002) identified the factors that contributed to truck accidents at intersections in urban areas by using Poisson and negative binomial regression models. They found that segment length, AADT, length of horizontal curve, crest curve, grade rate, length of vertical curve, number of lanes, no of signals within the segment and pavement width were significant factors affecting truck crash frequency.

Hummer et al. (1988) looked at the effect of turns by larger trucks at urban intersections. The study did not look at accident data but focused on the off-tracking of different sizes of
trucks during different turning maneuvers. In this study, computer simulation and field observations were used to analyze off-tracking.

Joshua and Garber (1992) performed a fault-tree analysis of large trucks accidents in America to identify the individual roles played by driver, vehicle, and environmental factors, as well as their interactions, in the accident mechanism. They identified wrong judgments of drivers, equipment failure in vehicles and excessive demand on driver and vehicle performance created by the environmental or roadway factors, as the prevalent causes of large vehicle accidents. Based on the findings, the study recommended a number of strategies to improve vehicle and roadway compatibility, to improve reliability of the vehicle and to provide better driver education.

Based on the descriptive statistics, Evans and Courtney (1985) identified certain factors that were likely to influence the bus accidents in Hong Kong. Accident incidence had been related to time of day, day of the week, time of year, weather conditions, driver's age and experience, hours on duty and policy-reported causes.

Zegeer et al. (1994) examined the characteristics of the crashes involving transit buses in America. Their analysis involved cross tabulation of selected variables and tested the differences in the resulting distribution. Bus crashes were then compared with crashes of other vehicle types for accident types and crash severity.

As stated above, our literature survey found very few studies that focused on heavy vehicle accident in developing countries. In one of the few studies, Taneerananon and Somchainuek (2005) identified the characteristics and causes of bus crashes in Thailand using three case studies. Their study identified three contributing elements: drivers’ errors, vehicle integrity and defects and roadside hazards. In another study, Maunder and Pearce (1998) examined the factors contributing to bus accidents in the kingdom of Nepal. They identified speeding, lack of proper traffic signal, mountainous road alignment, lack of bus bays and weak application of traffic regulations as the contributors of bus accidents.

Hamed et al. (1998) estimated two disaggregate models related to the time until accident occurrence and the number of accident injuries for the analysis of mini-bus traffic accidents in Jordan. Their results indicated that if the previous accident was severe, the time between the two accidents increased. The analysis results also suggested that the mini-bus drivers who were married and took few rests were associated with higher accident rates unlike those drivers who had long bus-driving and private vehicle-driving experiences.

3 OBJECTIVE OF STUDY
The objective of this study is to identify the factors that influence the severity of accidents involving heavy vehicles in Bangladesh. No study was found on heavy vehicle safety in Bangladesh even though heavy vehicle accidents represent a major portion of road crashes. It is hoped that the results of the study will provide transportation engineers and other road safety professionals with some useful insights to improve heavy vehicle safety in Bangladesh and in other developing countries.

4 MULTINOMIAL LOGIT MODEL
Among the unordered response models, the multinomial logit model is the most widely used in traffic safety research. Kim et al. (2007) used it to analyze police-reported crash data between 1997 and 2002 in North Carolina, USA while Savolainen and Mannering (2007) used it to predict the factors that influence the severity of motorcycles crashes. Ulfarsson and Mannering (2004) used it to explore differences in injury severity between male and female drivers in single and two-vehicle crashes involving passenger cars, pickups, sport-utility-vehicles and minivans. Shankar et al. (1996) considered environmental, roadway, vehicular,
and rider characteristics in their multinomial logit analysis of single-vehicle motorcycle crash-injury severity.

The severity of heavy vehicle accidents is normally classified into discrete categories which describe the injury severity (usually from no-injury to fatal accident with one or more categories in between). To show the development of the model, consider the probability of an accident ending in a specific injury-severity level. The probability of the nth crash ending with a severity outcome i is given by:

\[ P_{ni} = P(U_{ni} \geq U_{nj}), \quad \forall \ i, j \in I, i \neq j \]  

where \( U_{ni} \) is a function determining the severity, and I is a set of all possible, mutually exclusive severity categories. If we assume that \( U_{ni} \) has a linear-in-parameters form, it can be expressed as:

\[ U_{ni} = \beta_i x_n + \epsilon_{ni} \]  

where \( \beta_i \) is a vector of coefficients to be estimated for severity outcome i and \( x_n \) is a vector of exogenous variables for crash n. \( \epsilon_{ni} \) is the random component (an error term) that explains unobserved influences on injury severity. The term \( \beta_i x_n \) in this equation is the observable component of severity determination. From the equations (1) and (2), we have:

\[ P_{ni} = P(\beta_i x_n + \epsilon_{ni} \geq \beta_j x_n + \epsilon_{nj}), \quad \forall \ i, j \in I, i \neq j \]  

\[ P_{ni} = P(\beta_i x_n - \beta_j x_n \geq \epsilon_{nj} - \epsilon_{ni}), \quad \forall \ i, j \in I, i \neq j \]  

McFadden (1981) showed that assuming the error terms to have a generalized extreme value distribution will result in a closed form model given by:

\[ P_{ni} = \frac{\exp[\beta_i x_n]}{\sum_{j=1}^{I} \beta_j x_n} \quad \forall \ i \in I, \]  

The above model was estimated using the standard maximum likelihood procedure in STATA version 9.

5 DATA

This study used traffic accident data involving heavy vehicles in Bangladesh for the years 1998 to 2006. The data were extracted from the Micro Computer Accident Analysis Package (MAAP5) database maintained by the Accident Research Institute (ARI) at the Bangladesh University of Engineering & Technology (BUET). The crash data were generally compiled from the First Information Report (FIR) maintained by the police and subsequently entered into MAAP. The Transport Research Laboratory (TRL) of the United Kingdom developed this MAAP computer software package specifically for storage and analysis of road accident data.

A general limitation of police reported data is underreporting; people do not always report minor or non-injury accidents to the police. Also, accident report forms are not always properly and completely filled by police officers due to the lack of proper training and incentives. According to Kim et al. (2007), this underreporting will bias the estimate of the coefficient of a variable if the accident reporting rate is a function of the variable. Since hospital records of road accidents do not generally contain information on roadway and environmental characteristics, police records are still the best for this statistical analysis due the richness of the collected data although it has some limitations.

For the analysis of the heavy vehicle crash severity, this study used only the accidents that involved at least one heavy vehicle (minibus, bus, truck, heavy truck and oil-truck). Both the public transport (mini-bus, bus) and the freight transport (trucks) were considered together in because they often transport people and goods together. Often, on the roadway of Bangladesh,
a bus could be seen running with stack of goods on the roof (see Figure 1), while trucks would be loaded with passengers (see Figure 2).

Table 1 shows the descriptive statistics for the variables used in this study. The dependent variable is the heavy vehicle accident severity, classified in three categories: “Fatal Accident”, “Injury Accident” and “Non-Injury Accident”. The severity of accident is determined by the person with the most severe injury. A crash is considered as fatal if at least one person involved in the crash dies, while an injury crash is one in which at least one person is hospitalized or suffers some minor injuries without need of treatment in a hospital. Lastly, a non injury crash is defined as a crash associated with no injury but only damage to the vehicles or other properties. Of the 21,378 heavy vehicle accidents, 68% are classified as fatal accidents, 27% are classified as injury accidents and the rest are non-injury accidents or property damage only (PDO) accidents.

Table 1: Descriptive statistics of variables

<table>
<thead>
<tr>
<th>Variables (Description)</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No of Vehicles Involved</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Vehicle (1=Single vehicle; 0=Otherwise)</td>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td>Two Vehicles (1=Two Vehicles; 0=Otherwise)</td>
<td>0.39</td>
<td>0.49</td>
</tr>
<tr>
<td>Three or More Vehicles (1=Three or more Vehicles; 0=Otherwise)</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Presence of Median</strong> (1=Divider; 0=Otherwise)</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Types of Roadway Section</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Block (1=Mid-Block; 0=Otherwise)</td>
<td>0.76</td>
<td>0.43</td>
</tr>
<tr>
<td>Event Type</td>
<td>Value 1</td>
<td>Value 2</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Cross Intersection (1=Cross Intersection; 0=Otherwise)</td>
<td>0.05</td>
<td>0.22</td>
</tr>
<tr>
<td>T-Intersection (1=T-Intersection; 0=Otherwise)</td>
<td>0.08</td>
<td>0.27</td>
</tr>
<tr>
<td>Staggered Intersection (1=Staggered Intersection; 0=Otherwise)</td>
<td>0.01</td>
<td>0.10</td>
</tr>
<tr>
<td>Roundabout (1=Roundabout; 0=Otherwise)</td>
<td>0.02</td>
<td>0.13</td>
</tr>
<tr>
<td>Other Intersections (1=Other Intersections; 0=Otherwise)</td>
<td>0.08</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**Traffic Control & Operations**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncontrolled Intersection (1=Uncontrolled; 0=Otherwise)</td>
<td>0.80</td>
<td>0.40</td>
</tr>
<tr>
<td>Police-controlled (1=Police-controlled; 0=Otherwise)</td>
<td>0.05</td>
<td>0.22</td>
</tr>
<tr>
<td>Signalized (1=Signalized; 0=Otherwise)</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Signalized + Police Controlled (1=Signal + Police; 0=Otherwise)</td>
<td>0.04</td>
<td>0.20</td>
</tr>
<tr>
<td>Other Control (1=Other Control; 0=Otherwise)</td>
<td>0.09</td>
<td>0.28</td>
</tr>
</tbody>
</table>

**Types of Collisions**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head-on (1=Head-on; 0=Otherwise)</td>
<td>0.15</td>
<td>0.35</td>
</tr>
<tr>
<td>Rear-End (1=Rear-End; 0=Otherwise)</td>
<td>0.16</td>
<td>0.37</td>
</tr>
<tr>
<td>Right-angle (1=Right-angle; 0=Otherwise)</td>
<td>0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Side-swipe (1=Side-swipe; 0=Otherwise)</td>
<td>0.07</td>
<td>0.25</td>
</tr>
<tr>
<td>Overturn (1=Overturn; 0=Otherwise)</td>
<td>0.41</td>
<td>0.49</td>
</tr>
<tr>
<td>Hit-pedestrian (1=Hit-pedestrian; 0=Otherwise)</td>
<td>0.10</td>
<td>0.29</td>
</tr>
<tr>
<td>Other Collision (1=Other Collision; 0=Otherwise)</td>
<td>0.11</td>
<td>0.31</td>
</tr>
</tbody>
</table>

**Road Surface Condition**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry (1=Dry; 0=Otherwise)</td>
<td>0.95</td>
<td>0.22</td>
</tr>
<tr>
<td>Wet (1=Wet; 0=Otherwise)</td>
<td>0.04</td>
<td>0.20</td>
</tr>
<tr>
<td>Muddy (1=Muddy; 0=Otherwise)</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Others Surface Condition (1=Other Conditions; 0=Otherwise)</td>
<td>0.00</td>
<td>0.06</td>
</tr>
</tbody>
</table>

**Road Class**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>National (1=National; 0=Otherwise)</td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td>Regional (1=Regional; 0=Otherwise)</td>
<td>0.13</td>
<td>0.33</td>
</tr>
<tr>
<td>Feeder (1=Feeder; 0=Otherwise)</td>
<td>0.14</td>
<td>0.35</td>
</tr>
<tr>
<td>Rural Road (1=Rural Road; 0=Otherwise)</td>
<td>0.05</td>
<td>0.22</td>
</tr>
<tr>
<td>City Road (1=City Road; 0=Otherwise)</td>
<td>0.25</td>
<td>0.44</td>
</tr>
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</table>

**Special Road Features**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Road Features (1=No Road Features; 0=Otherwise)</td>
<td>0.96</td>
<td>0.20</td>
</tr>
<tr>
<td>Bridge (1=Bridge; 0=Otherwise)</td>
<td>0.02</td>
<td>0.14</td>
</tr>
<tr>
<td>Culvert (1=Culvert; 0=Otherwise)</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Speed-Breaker (1=Speed-Breaker; 0=Otherwise)</td>
<td>0.00</td>
<td>0.05</td>
</tr>
</tbody>
</table>

**Road Environment** (1=Urban; 0=Otherwise)

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minibus (1=Minibus; 0=Otherwise)</td>
<td>0.18</td>
<td>0.38</td>
</tr>
<tr>
<td>Bus (1=Bus; 0=Otherwise)</td>
<td>0.38</td>
<td>0.48</td>
</tr>
<tr>
<td>Truck (1=Truck; 0=Otherwise)</td>
<td>0.43</td>
<td>0.49</td>
</tr>
</tbody>
</table>

**Driver Age**

<table>
<thead>
<tr>
<th>Event Type</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below25 (1=Below25; 0=Otherwise)</td>
<td>0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Age 25 to 55 (1=Age 25 to 55; 0=Otherwise)</td>
<td>0.32</td>
<td>0.47</td>
</tr>
<tr>
<td>Above55 (1=Above55; 0=Otherwise)</td>
<td>0.02</td>
<td>0.12</td>
</tr>
</tbody>
</table>
6 RESULTS AND DISCUSSIONS

The estimates of the model are shown in Table 2 along with the standard error. Note that non-injury accidents or property damage only (PDO) accidents are selected as the base case and the estimated coefficients therefore show the effect of the variable on the estimated severity level (fatal or injury) relative to PDO.

The result shows that some of variables are not significant but still those are retained in the model as long as at least one of the variables for the factor is statistically significant. Kockelman and Kweon (2004) suggested keeping the variables with low statistical significance in the model if they belong to factors that have some significant effect on injury severity. It eases the comparison and interpretation of the estimates. Therefore, a more liberal confidence level of 90% has been used to adjust the potential decrease in efficiency.

Table 2: Parameter estimation results of severity analysis of heavy vehicles

<table>
<thead>
<tr>
<th>Variables</th>
<th>Injury Accident</th>
<th>Fatal Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No of Vehicles Involved (Reference: Single Vehicle)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Vehicles</td>
<td>-0.188(0.131)</td>
<td>-0.714(0.129)**</td>
</tr>
<tr>
<td>More than Two Vehicles</td>
<td>0.180(0.300)</td>
<td>-0.463(0.314)</td>
</tr>
<tr>
<td><strong>Types of Roadway Section (Reference: Cross Intersection)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-Intersection</td>
<td>-0.254(0.147)*</td>
<td>-0.325(0.153)**</td>
</tr>
<tr>
<td>Staggered Intersection</td>
<td>-0.541(0.372)</td>
<td>-0.747(0.372)**</td>
</tr>
<tr>
<td>Roundabout</td>
<td>-0.725(0.184)**</td>
<td>-0.606(0.200)**</td>
</tr>
<tr>
<td>Other Intersections</td>
<td>-0.212(0.205)</td>
<td>-0.258(0.205)</td>
</tr>
<tr>
<td>Mid-Block (Not Intersection)</td>
<td>-0.354(0.151)**</td>
<td>-0.368(0.153)**</td>
</tr>
<tr>
<td><strong>Traffic Control &amp; Operations (Reference: Uncontrolled Intersection)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Police-controlled</td>
<td>-0.373(0.134)**</td>
<td>-0.737(0.137)**</td>
</tr>
<tr>
<td>Signalized</td>
<td>-0.241(0.316)</td>
<td>-0.324(0.318)</td>
</tr>
<tr>
<td>Signalized + Police Controlled</td>
<td>-0.629(0.145)**</td>
<td>-1.336(0.155)**</td>
</tr>
<tr>
<td>Other Control</td>
<td>-0.031(0.148)</td>
<td>-0.130(0.146)</td>
</tr>
<tr>
<td><strong>Types of Collisions (Reference: Rear-End)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head-on</td>
<td>0.385(0.122)**</td>
<td>0.239(0.121)**</td>
</tr>
<tr>
<td>Right-angle</td>
<td>-0.254(0.183)</td>
<td>-0.286(0.194)</td>
</tr>
<tr>
<td>Side-swipe</td>
<td>-0.461(0.116)**</td>
<td>-0.797(0.118)**</td>
</tr>
<tr>
<td>Overturn</td>
<td>1.287(0.279)**</td>
<td>0.825(0.277)**</td>
</tr>
<tr>
<td>Hit-pedestrian</td>
<td>20.406(0.00)</td>
<td>20.977(0.080)**</td>
</tr>
<tr>
<td>Other Collision</td>
<td>-0.799(0.127)**</td>
<td>-1.119(0.127)**</td>
</tr>
<tr>
<td><strong>Presence of Median (Divider)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.634(0.099)**</td>
<td>-0.828(0.100)**</td>
</tr>
<tr>
<td><strong>Road Surface Condition (Reference: Dry)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet</td>
<td>-0.306(0.213)</td>
<td>-0.466(0.210)**</td>
</tr>
<tr>
<td>Muddy</td>
<td>-1.233(0.903)</td>
<td>-1.249(0.883)</td>
</tr>
<tr>
<td>Others Surface Condition</td>
<td>-1.494(0.597)**</td>
<td>-1.034(0.558)*</td>
</tr>
<tr>
<td><strong>Road Class (Reference: National)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>0.345(0.176)**</td>
<td>0.299(0.173)*</td>
</tr>
<tr>
<td>Feeder</td>
<td>0.727(0.209)**</td>
<td>0.746(0.206)**</td>
</tr>
<tr>
<td>Rural Road</td>
<td>0.973(0.375)**</td>
<td>1.172(0.371)**</td>
</tr>
<tr>
<td>City Road</td>
<td>-0.712(0.150)**</td>
<td>-1.300(0.148)**</td>
</tr>
</tbody>
</table>

Special Road Features (Reference: No road Features)
The number of vehicles involved in a crash was found to be a significant factor affecting the severity risks of heavy vehicle crashes. Our analysis showed that single vehicle crashes were more severe than two-vehicle crashes ($\beta = -0.714$). Single vehicle crashes were predominantly crashes involving pedestrian, cyclists and other non motorized vehicles such as rickshaws and pushcarts which were expected to be more severe because these road users were unprotected and very vulnerable. Other single vehicle crashes involved hit-fixed-objects and hit-parked vehicle crashes which were expected to be less serious due to better occupant protection and relatively low speed compared to many developed countries. This result was consistent with the studies by Hamed et al. (1998) and Barua and Tay (2007) where the single vehicle crashes were found to have higher severity.

Junction type was also found to have a significant effect on the crash severity of heavy vehicle crashes. The accidents at cross junctions were found to be more severe than that of the T-junctions, staggered junctions and roundabouts. Studies had found that staggered intersections are 1.5 to 2.0 times safer than cross intersection for the same traffic flow (Headman, 1990). Modern roundabouts were considered as an innovative design element that could significantly improve intersection safety (Elvik, 2003; Flannery, 2001; Persaud et al., 2001).

Our results showed that the types of traffic control present at the crash location had a significant effect on the severity of heavy vehicle crashes. Crashes were less likely to be fatal when the intersections were either police-controlled or signalized coupled with police-control as compared to uncontrolled intersections. Police presence aided with traffic signal seemed to be more effective in reducing severity risk involving heavy vehicle than the presence of traffic police alone. On the contrary, only signalization in absence of police had no effect on the severity of heavy vehicle crashes. In a study of intersections of Dhaka, Yasmin (2007) found that no one obeyed the traffic signal until and unless traffic police was present. Police compelled the driver to slow down and follow the speed limit as well as the loading limit. According to Elvik and Vaa (2004), stationary speed enforcement, like police presence would ensure compliance with speed limit, thus reducing the number and severity of accidents.

Our model estimates showed that among the different collision types, hit-pedestrian crashes were associated with significantly higher fatality risk ($\beta = 20.977$). The result was expected since pedestrian tended to be more vulnerable due to the lack of protection and

<table>
<thead>
<tr>
<th></th>
<th>Bridge</th>
<th>Culvert</th>
<th>Speed-Breaker</th>
<th>Road Environment (Urban)</th>
<th>Types of Vehicles (Reference: Bus)</th>
<th>Driver Age (Reference: Age 25 to 55)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.505(0.375)</td>
<td>-1.059(0.513)**</td>
<td>-1.535(0.484)**</td>
<td>-0.198(0.146)</td>
<td>Minibus 0.005(0.101)</td>
<td>Truck -0.269(0.085)**</td>
</tr>
<tr>
<td></td>
<td>0.193(0.372)</td>
<td>-0.779(0.489)*</td>
<td>-1.764(0.459)**</td>
<td>-0.396(0.144)**</td>
<td>Minibus</td>
<td>Truck -0.187(0.102)*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Truck -0.185(0.085)**</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Minibus 0.187(0.102)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Truck -0.185(0.085)**</td>
<td></td>
</tr>
</tbody>
</table>
| Log likelihood | -13820.871 | Number of observation = 21378 | Chi-square = 4960.81 | P-value < 0.0001 | Pseudo-R-Square = 0.1522 | Base case: Non-injury or PDO accidents

Standard errors are in parentheses. Level of significance: *$p<0.05$, **$0.05<p<0.10$
hence would suffer more serious injury when hit by a heavy vehicle. Also, the fronts of the buses and trucks in the developing countries were not designed to be “forgiving” in impacts with vulnerable road users. Chawla et al. (2000) and Kajzer et al. (1992) suggested that the fronts of the buses and trucks could be designed so that impact forces in a heavy vehicle-pedestrian collision could be reduced significantly. Our study also showed that overturning and head-on collisions increased the probability of both fatal and injury accidents. These findings were consistent with the results of Barua and Tay (2007).

Road divider significantly reduced the probabilities of both the fatal accidents ($\beta = -0.828$) and injury accidents ($\beta = -0.634$). Medians should have beneficial effects on safety since they would separate the opposing traffic, discourage inappropriate crossing of the road by pedestrians and provide room for turning lanes. The dividers would also reduce the approach speed as well as prevent head-on, opposite direction sideswipe and same direction sideswipe collision. Walker and Lines (1991) reported that the road with a median had an accident rate per vehicle-kilometre that was two-thirds that of undivided roads.

Our analysis found that road crashes were less likely to be fatal when the road surface was wet due to the rain as compared to dry road surface condition but injury crashes were not influenced by the road surface condition. There was a reduction in the level of severity in wet conditions due to slow and more cautious driving by the drivers. In wet condition, a greater number of vehicles were involved in minor collisions due to the reduction in skid resistance of road surface. This in turn would advantageously reduce accident severity (Edwards, 1998).

Our results indicated that road accidents involving heavy vehicle on the rural and feeder roads were more likely to be fatal or injurious while accidents on the city roads ($\beta = -1.3$) were less likely to be fatal or injurious than the national highways of Bangladesh. These findings could be explained by the fact that the heavy vehicles that ran on the feeder and rural roads were of lower qualities and were often overloaded and overcrowded. Hence, the accidents on these roads tended to be more severe. On the contrary, the vehicles plying the city roads had to maintain certain standards because their fitness would be randomly checked by the police and the mobile court, and failing to meet the fitness standards would cost them a huge fine.

The safety of the road users was influenced both by the absolute speed of the vehicle and the variation in speeds among vehicles on the road (Noguchi, 1991). Speed-reducing devices were intended to force vehicles to reduce speed, so that the risk of accidents would be reduced. Speed breaker, culverts, speed humps were some of the traffic calming measures that were used in some developing countries to reduce the speed of vehicles. Our analysis showed that these measures significantly reduced the probabilities of both fatal and injurious accidents. According to Elvik and Vaa (2004), speed humps corresponded to a 33% reduction in speed which in turn reduced the number of injury accidents, for a given amount of traffic, by around 50%.

Heavy vehicle accidents in rural areas were more likely to be fatal than the accidents in urban areas ($\beta = -0.396$). Many different types of risk factors might contribute to the increased injury and fatality risks on rural roads. Increased crash severity on rural roads might occur because crash characteristics were different on rural than urban roads. For example, rural drivers might be more likely to have head-on crashes because traffic streams were often not divided. Rural drivers might also be more likely to have single vehicle collisions with stationary objects because roadsides did not have guardrails. These two types of crashes would have an increased likelihood of producing fatalities and injuries compared to rear-end or sideswipe collisions (Muelleman et al., 1993 and Weiss et al., 2001). Studies had reported that motor vehicle injury fatality rates had been consistently higher in rural areas than in urban areas (NHTSA, 2001).

With regards to the vehicle type, our analysis showed that trucks and minibuses were associated with less severe accidents than buses. Also, our results showed that the probability
of fatal accident was greater for the driver aging between 25 to 55 years than that of the age below 25. The result could be due to the better reaction time of younger drivers, resulting in a lower impact speed.

7 CONCLUSION
This study examined the factors associated with injury severity of heavy vehicle accidents in Bangladesh. A multinomial logit model was applied to a sample of heavy vehicle accident crashes from 1998 to 2006. The model results showed that severity of heavy vehicle accidents increased when there was either a head-on collision, hit-pedestrian or single vehicle collision. On the other hand, presence of police and speed-hump significantly reduced the likelihood of severe heavy vehicle accidents. A heavy vehicle accident tended to be less severe when the accident occurred on culverts or involved a young driver.

The above results suggest that improving the vehicle fitness and preventing overloading may be effective in reducing the severity of heavy vehicle crashes. Also, more driver training and education aimed at improving pedestrian conspicuity and understanding the vulnerability of pedestrians may reduce crashes involving pedestrian and thus reduce the probability of severe crashes. The provision of traffic medians is likely to be effective in reducing the severity of heavy vehicle crashes as well. Finally, more resources should be devoted to traffic enforcement in general and police control to improve road safety in Bangladesh.

8 ACKNOWLEDGEMENT
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REFERENCES


Investigating Drivers’ Behavior Change by Signal Countdown Devices at Intersections in Beijing

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ABSTRACT

Several years ago, signal countdown devices at intersections in Beijing were removed after the replacement of pre-timed controllers by actuated traffic controllers. Currently, concerning the various traffic problems at intersections, Beijing PPCC (People’s Political Consultative Conference) recommended the restoration of signal countdown devices in order to change aggressive and unsafe drivers’ behavior at Intersections in Beijing on the 2007 NPC (the National People’s Congress) and CPPCC (the Chinese People’s Political Consultative Conference). This study investigated the effects of Signal Countdown devices on driver’s behavior by installing the devices at four intersections located in the southeast of Beijing. The before-and-after study analyzed the change of driving behavior through intersections on yellow and red separately. By collecting data on traffic flows, the study estimated how much influence the devices have on drivers’ driving behavior. The data was obtained by Metro Count 5600 and video cameras. The result shows that signal countdown devices do have some measurable effects on driver’s behavior.

Keywords: Signal Countdown, Traffic Safety, Driving Behavior, Yellow-Running, Red-Running

INTRODUCTION

Signal countdown devices have become widely used in Beijing since 2003. This device displays the remaining seconds of current signal phase either by time bars or by second digits by synchronizing time with traffic signal controllers. The purpose of the devices is to provide related traffic control
information for road users so that they could utilize the information and complete their travel across
the intersections safely, efficiently, and smoothly.

Because of its significance in urban traffic management, some studies have been conducted. Lum (1)
researched driver response along an approach to a signalized intersection installed with a green
signal countdown device (GSCD). His conclusions were that red-light running violations were
significantly reduced by about 65% within 1.5 months after GSCD installation but the effectiveness
of GSCD tended to dissipate over time as the violation numbers bounced back to almost the same
level before GSCD installation. On the other hand, the numbers of vehicles choosing to stop during
the onset of amber had increased significantly by about 6.2 times within 1.5 months after GSCD
installation.

Wang Yan and Yang Xiaoguang (2) thought there is a likelihood that some drivers would rush
through the intersection with signal countdown devices at end of green, which is dangerous to cause
crash with other vehicles from other approaches. They suggested prolonging the green interval at
the intersections with countdown devices. However, that practice would lower the capacity.

Some studies on pedestrian countdown timers have been conducted by Minnesota Department of
Transportation (3), Markowitz, (4), Sciortino, Huey, (5) and Steven (6). The conclusion from
Minnesota Department of Transportation was that the CDTs is helpful in pedestrian’s crossing
decision making. Markowitz, (4) found a significant reduction in pedestrian-involved crashes at
intersections where CDTs have been installed. Huey (5) found that drivers at one intersection with
CDTs were less likely to enter an intersection at the end of the amber phase than those at another
nearby intersection without the CDTs. Steven (6) concluded that drivers use the information
provided by pedestrian countdown timers (CDTs) to improve their driving decisions. In all, CDTs
can results in safer driving actions.

In a previous study, Yulong He(8) surveyed 400 valid questionnaires in 2007, including 200 drivers
and 200 pedestrians. The result shows that the majority of people prefers signal countdown devices
and believes that the device is useful to alleviate the anxiety waiting for the green signal.

After the replacement of pre-timed traffic controllers by actuated controller several years ago in
Beijing, signal countdown devices at intersections were removed. Actually, many drivers in Beijing
are accustomed to signal countdown devices and they said “we will control and adjust our speeds
according to the countdown time displayed”. Chinese government is going to build a "harmonious
society", it mean the government will pay more attention to public’s opinions. It is necessary to
estimate how much influence the devices have on drivers’ driving behavior.

STUDY OBJECTIVE

The objective of this study was to fully understand drivers’ behavior effects of the signal countdown
devices, Beijing Traffic Management Bureau selected four intersections to conduct tests on signal
countdown devices, including Puhuangyu Intersection, Fangqun Intersection, Fangxing Intersection
and BJUT South Gate Intersection (shown in Figure 1). The four intersections are located in the
southeast of Beijing. Southbound and northbound approaches of Puhuangyu Intersection are
arterials, which connect the 2nd ring road (southern segment) and the 3rd ring road (southern
segment). Fangqun Intersection and Fangxing Intersection both are intersections of connectors and
branch roads. Fangqun Intersection is four-legged; Fangxing Intersection is four-legged with three
approaches. BJUT South Gate Intersection is the intersection of an arterial and a ramp of the 4th
ring road. Single-digit (post phase display timer showing countdown time from 9 seconds) and
double-digit (displaying full phase countdown time) signal countdown devices (shown in Figure 2) were installed at these 4 intersections. Based on the field data collected by MetroCount 5600 and video cameras, before-and-after study methodology is used to analyze the change of driving behavior through intersection on yellow and red separately.

![FIGURE 1 Location of the four intersections in the southeast of Beijing, China](image1)

![FIGURE 2 Signal countdown devices installed at a tested intersection](image2)

**RESEARCH METHODOLOGY**

In order to conduct comparison analysis before and after the installation of signal countdown devices at the above 4 intersections, intersection observation and traffic flow data collection for 7 consecutive days (6 hours per day, 11:30 ~ 13:30 at noon, 17:00 ~ 19:00, the evening peak, and 20:00 ~ 22:00 at night) using video cameras and MetroCount 5600 were respectively carried out for both before and after the installation of signal countdown devices at the intersections.

![FIGURE 3 Traffic flow data collection device (MetroCount)](image3)
Video camera recording on driving behaviors was carried out for the total 15 approaches of the 4 intersections (BJUT South Gate Intersection, Puhuangyu Intersection, Fangqun Intersection, and Fangxing Intersection) twice (once before the installation of signal countdown devices and once after), with the total recording hours of 1260 hours (15 approaches × 6 hours per day × 7 days of observation × 2 times). Due to problems like site visibility, weather, poor recording angles, etc., some recording data were invalid. Valid recording data were processed by human observation and judgment and the number of red-light running and the number of vehicles passing the intersections during yellow during the changing intervals of the traffic signals by the statistical unit of one hour were collected for each of the 15 approaches.

MetroCount 5600 were installed on the through lanes, 10-meter after the stop bars and they collected the vehicle speed, vehicle headway, and traffic volumes for each approaches. The data collection using MetroCount 5600 were carried out 7 days respectively for both before and after the installation of the signal countdown devices, with the total collection time of 14 days.

STATISTICAL ANALYSIS

Behavior Analysis on Passing during Yellow based on Negative Traffic Load

1. Behavior Comparison Analysis on Passing during Yellow before and after Signal Countdown Device Installation

Due to the variation of the number of the through lanes at the above 4 intersections, in order to carry out the behavior analysis on passing during yellow before and after the signal countdown device installation, the paper selected negative traffic load (the ratio of traffic volume to capacity) and the number of vehicles passing during yellow per hour as the statistical parameters. Under different negative traffic loads, the distribution of drivers’ behaviors of passing during yellow is shown in Figure 4. Before the installation of signal countdown devices at the intersections, drivers were unable to know the exact finish time of the green time and the behaviors of passing during yellow were relatively common. As shown in the figure, noticeably, when V/C>0.7, the number of passing behaviors during yellow is significantly higher than the situation of other negative traffic loads. As the traffic volume increases, the road congestion degree increases and the time across the intersection will increase correspondingly. Thus, the approaching drivers’ desire to pass the intersections will become more imminent and it will lead to the increase of passing behaviors during yellow with no signal countdown device installation.

![未安装倒计时信号灯v/c和驾驶员黄灯通过路口行为图](image)

FIGURE 4  Number of vehicles passing during yellow before signal countdown device installation
After the installation of the signal countdown devices, the drivers’ behavior of passing during yellow (Figure 5) showed some significant changes compared with the before scenario. After the installation, when \( V/C < 0.7 \), the number of drivers’ behavior of passing during yellow significantly reduced, from the average of 14.9 per hour before the installed to the average of 8.4 per hour. The signal countdown devices accurately show the exact finish time of the green and they significantly lower the behavior of passing during yellow for drivers aware of no speeding through intersections during yellow. When \( V/C > 0.7 \), as the road congestion degree increases, the approaching drivers’ desire to pass the intersections will become more imminent. Even under the situation of signal countdown device existence, drivers’ behavior of passing during yellow is still significantly higher the situation of other negative traffic loads. However, the comparison before and after the signal countdown device installation shows that the average number of passing during yellow decrease from 36.1 per hour in the before scenario to 11.8 per hour in the after scenario.

2. Behavior Comparison Analysis on Red-Light Running before and after Signal Countdown Device Installation

In order to carry out behavior analysis on red-light running before and after the signal countdown device installation, the paper selected negative traffic load (the ratio of traffic volume to capacity) and the number of red-light running vehicles per hour as the statistical parameters. Under different negative traffic loads, the distributions of drivers’ behaviors of red-light running are shown in Figure 6 and 7.
Figure 6 and 7 are the scatter diagrams of the number of red-light running and the negative traffic load before and after the signal countdown device installation respectively. With no signal countdown device installation, the number of red-light running drivers is relatively high and when V/C>0.5, the number increases. After the signal countdown device installation, when V/C>0.5, even though the negative traffic load increases and the traffic congestion degree increases, the average number of red-light running is not higher than the situation when V/C<0.5.

**Significance Analysis of Effects of Signal Countdown Devices on Driving Behaviors at Intersections**

The paper compared the traffic flow and driving behavior (number of passing during yellow and number of red-light running) of the 15 approaches per hour respectively, carried out statistical analysis on the data before and after the signal countdown device installation, and studies the significance of behavior changes of passing during yellow and red-light running at each intersection.

1. Significance analysis of effects of signal countdown devices on driver behavior of passing during yellow at intersections

The traffic volume and driver behavior data on the through lanes of all the intersection approaches during the statistical time periods are shown in Table 1. In Table 2, the statistical variable $Z_{Stat}$ under the confidence level of 95%, shows that the drivers’ behaviors of passing during yellow after the signal countdown device installation is significantly lower than the situation with no signal countdown device installation.

**Table 1  Driving behavior of passing during yellow before and after signal countdown device installation**

<table>
<thead>
<tr>
<th>Number of passing during yellow in statistical time period (Traffic Volume in statistical time period) b</th>
<th>Number of vehicles passing during yellow per 1000 vehicles</th>
<th>Statistical time period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
a is the ratio of number of passing during yellow to traffic volume times 1000, i.e. $31.48 = \frac{1314}{41752} \times 10^3$;
b is the total average daily traffic volume through and turning left at all approaches of the intersections in the statistical time period.

Table 2  Statistical test on driving behavior of passing during yellow before and after signal countdown device installation

<table>
<thead>
<tr>
<th>Test description</th>
<th>Statistical Test Variable ($Z_{\text{Stat}}$) and 95% confidence level ($\text{SIG}$) $^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical variable</td>
<td>$Z_{\text{Stat}}$</td>
</tr>
<tr>
<td>With SCD installation</td>
<td>15.67$^b$</td>
</tr>
</tbody>
</table>

$^a$ means that the critical values of $Z$, the statistical test variable, under the confidence level of 95% ($\alpha = 0.5$, two-tailed test) are $\pm 1.96$. “√” means significance statistically and “×” insignificance statistically;

b The computing equation of $Z_{\text{Stat}}$ is shown as follows: $p_1$ is the percentage of number of vehicles passing during yellow with no signal countdown device installation and $p_1 = \frac{1314}{41752} = 31.48 \times 10^3$, as shown in Table 2; $p_2$ is the percentage of number of vehicles passing during yellow after signal countdown device installation and $p_2 = \frac{660}{43195} = 15.28 \times 10^3$; $p$ is the average percentage of number of vehicles passing during yellow and $p = \frac{(1314 + 660)}{(41752 + 43195)} = 23.24 \times 10^3$.

$$Z_{\text{Stat}} = \frac{(31.48 - 15.28) \times 10^{-3}}{\sqrt{23.24 \times 10^{-3} \times (1 - 23.24 \times 10^{-3}) \times \left(\frac{1}{41752} + \frac{1}{43195}\right)}} = \frac{p_1 - p_2}{\sqrt{p(1-p)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

If the test variable is negative, it means that there are more behaviors of passing during yellow with signal countdown device installation than the situation without the installation.

Table 2, the statistical test table on driving behavior of passing during yellow before and after signal countdown device installation, shows that the driving behavior of passing during yellow after signal countdown device installation is significant less than the situation without the installation.

2. Significance analysis of effects of signal countdown devices on driver behavior of red-light running at intersections

Table 3  Driving behavior of red-light running before and after signal countdown device installation

<table>
<thead>
<tr>
<th>Number of red-light running in statistical time period (Traffic Volume in statistical time period)</th>
<th>Number of red-light running per 1000 vehicles</th>
<th>Statistical time period</th>
</tr>
</thead>
</table>
Table 4  Statistical test on driving behavior of red-light running before and after signal countdown device installation

<table>
<thead>
<tr>
<th>Test description</th>
<th>Statistical Test Variable ($Z_{Stat}$) and 95% confidence level (SIG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With SCD installation</td>
<td>$5.28$</td>
</tr>
</tbody>
</table>

The statistical test in Table 4 shows that the driving behavior of red-light running after signal countdown device installation is significant less than the situation without the installation.

CONCLUSIONS

The paper conducted statistical analysis and tests on the driving behavior of passing during yellow and red-light running at all approaches of the 4 intersections before and after signal countdown device installation and the results show that the installation of signal countdown devices does have certain influence on drivers’ behavior at the approaches of the intersections.

Before the signal countdown device installation at the intersections, the driving behavior of passing during yellow increases as the hourly traffic volume increases.

After the signal countdown device installation (second-digits) at the intersections, the driving behavior of passing during yellow significantly decreases compared with the situation of no installation. Although the driving behavior of red-light running is still high, however, it is significantly less than the situation without the installation.

The above conclusions are based on the observation and analysis of one-week’s data before and after the signal countdown device installation. Some researches show that the effects of the signal countdown devices on drivers’ behavior will change as the time passes. Further study of assessment and analysis by increasing the sample size, selecting intersections of different volumes as research subjects, and expanding the assessment time periods before and after the signal countdown device installation is needed.

ACKNOWLEDGEMENTS

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REFERENCES

1. K.M. Lum, Harun Halim. A before-and-after study on green signal countdown device installation,
2. Wang Yan and Yang Xiaoguang, Discussion on Setting Traffic Signals with Counting down Display Unit at Intersection Based on Traffic Safety, School of Transportation Engineering, Tongji University, Shanghai, 200092, Department of Traffic Management, Hunan Public Security College, Changsha, 410006


8. Yulong He, Jie Zhang, Xiaoduan Sun, Ran Wei, Investigating Road Users’ Preference on Signal Countdown Devices at Intersections in Beijing, the 88th TRB Annual Meeting, 2009
ACCIDENT CHARACTERISTICS BY ROAD TYPES ON SINGAPORE ROADS

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ABSTRACT
Singapore is an urbanized city state. The residential areas, industrial areas and central business districts are linked by expressways, arterial roads, collector roads, local access roads and more than 1500 signalised intersections. As such, it is prudent that we have a good understanding of the characteristics of accidents that occurred at these types of locations so that we can target our efforts to incorporate the necessary measures to improve safety at these locations.

Accident characteristics of expressways, one-way roads, two-way divided/undivided roads, slip roads and junctions are analysed in this paper, with reference to vulnerable road uses such as pedestrians and motorcyclists. Brief descriptions of existing or possible new measures to manage the identified accident characteristics are also mentioned in this paper.

1 INTRODUCTION
Singapore is an urbanized city state. The residential areas, industrial areas and central business districts are linked by expressways, arterial roads, collector roads, local access roads with more than 1500 signalised intersections.

Being a dynamic country, Singapore aims to ensure that roads are built to serve new developments and support economic growth. As such, the road network is increasing over the years. As at 2007, the island-wide road network covers 153 km of expressways, 613 km of arterial roads and 2,531 km of collector and local access roads (LTA, 2008a). The 153 km of expressways consists of nine (9) expressways (with speed limit of 70kph (in the 3 km long tunnel), 80 kph and 90 kph) that brought motorists from the residential area in various parts of Singapore to the central business district in the central and the south, the industrial areas in the west and the international airport in the east. The arterial roads are usually dual-carriageway with major traffic corridors serving different parts of Singapore, and alternative routes to expressways. The collector and local access roads are usually residential roads. The speed limit of these road types range from 50 to 70 kph. Expressway slips are the on-ramps and off-ramps leading to and from expressways with speed limit of 40/50 kph. As such, with increasing road network, coupled with increasing vehicle population, the risk of accidents is relatively higher.

There are measures to ensure vehicles are serviceable e.g. mandatory regular vehicle inspection to minimize possibility of vehicle breakdown and thus road accidents. However, it is imperative to gain a deeper understanding of accident characteristics by road types, in view of the road intended functionality and the posted speed limits. This paper is a preliminary study of the accident characteristics for various types of road types in Singapore, with
reference to the predominant vulnerable road users i.e. motorcyclists and pedestrians. Some substantial engineering treatments measures have been carried out in improving road safety for them.

Our commitments to explore innovative solutions to enhance road safety for all users will continue. We strongly believe that a good understanding of accident characteristics is the fundamental requirement to any road safety initiatives. To this end, while we are working on the application of more of these measures, more can be explored to improve the safety for these users through vigorous analysis of the data. More detailed study such as using Geographic Information System (GIS) to identify more detailed characteristics pertaining to spatial distribution locations (e.g. near residential area, business area); and advanced statistical modelling techniques (e.g. the relationships between the revision of speed limit, land uses, etc. and accident characteristics) of these road types with respect to the vulnerable road users and other road users can be carried out. This would enable formulation of road safety initiatives to fully capitalize on the resources available to achieve LTA mission of “A people-centred land transport system”.

2 DEFINITIONS

The definitions used in this paper are as follows:

i) fatal accident – an accident in which one or more persons is/are killed within 30 days of the accident

ii) Injury accident – any accident in which at least one party involved in the accident is conveyed to hospital from the accident scene by an ambulance, or if conveyance to hospital is done through other transport, the party is subsequently hospitalized, or given outpatient medical leave of 3 days or more

iii) Divided road – A two-way road separated by a kerbed centre divider with speed limit from 50 kph to 70 kph. These are usually arterial roads, with some from the residential roads.

iv) Undivided road – A two-way road separated by single/double white line/chevron marking at the centre of the road with speed limit from 40 kph to 50 kph. These are usually found in residential areas.

v) One-way road – One way road ranging from one lane to six lanes with speed limit 40 kph to 60 kph. The roads can be arterial roads, collector or local access roads.

vi) Expressway slip – the on-ramp or off-ramp leading to and from expressway with speed limit at 40/50 kph.

vii) Light vehicles - Cars and Light Goods Vehicles (LGV)

viii) Heavy vehicles – Buses and Heavy Goods Vehicles (HGV)

ix) Child – road users less than 15 years old

x) Youth – road users between 15 and 24 years old

xi) Elderly – road users more than or equal to 65 years old

3 SOURCE OF DATA

The accident data are extracted from Traffic Accident Analysis Module (TAAM), a GIS-based accident analysis software developed by LTA for accident data retrieval and analysis, with raw data obtained from Traffic Police Singapore. Users can use the system to make multi-query to obtain accident statistics for specific locations and time periods, to query the database by driver, road, vehicles characteristics, and to generate reports to be sent to the screen, to a file, or to a printer. The graphical interface of TAAM allows the viewer to
see on-screen maps of accident locations and to select specific nodes and links of interest at a click of the mouse (Hau et al., 2007).

4 GENERAL ACCIDENT TREND

In order to have better understanding of the accident situation in Singapore, there is a need to have an understanding of the general accident situation in Singapore. As observed from Figure 1, for the past ten years, the trend of fatality rate and injury rate by 10,000 vehicles shows that there is gradual decline with the lowest point in year 2005. This is followed by a slight increase which seems to start to taper and drop in 2007. As at Year 2008, the fatality rate and injury rate is 2.5 fatalities and 123 injuries per 10,000 vehicles, respectively.

Figure 2 shows the proportion of accidents that occur on different types of road in Singapore, based on five years of accident data from 2004 to 2008. There is a total of 37,928 accidents altogether. As observed, majority of the accidents occur at divided roads and signalized junctions, with a proportion of 21% and 18% respectively. This is followed by accidents at expressways with a proportion of 18% and undivided roads at 11%.

Figure 1: Fatality and Injury rate (by 10,000 vehicles) from Year 1999 to 2008
Figure 2: Percentage distribution of accidents at different types of roads

Figure 3 shows the general accident trend of all road traffic types over the past five years. It can be observed that there is an increase in numbers of accidents for most of the roads, with the divided roads and expressways most prominent. There is an increase of about 30% generally. When 5 years of accidents are segregated into accidents based on most vulnerable road users (i.e. when an accident occurred between motorcycle and pedestrian, it is classified as pedestrian accident as pedestrian is the most vulnerable in these two groups of road user), it is observed that 54% of accidents are motorcyclists accidents, followed by light vehicles users (i.e. cars and light goods vehicles) at 22% and pedestrians at 12% (Figure 4). When these road users are segregated according to the types of roads (Figure 5), it is observed that motorcyclists accidents are of higher proportion in expressways slips (72%), expressways(72%) and unsignalised junctions (60%). The light vehicles are of higher proportion in signalised junctions (33%) and the pedestrians are of higher proportion in divided, undivided and one-way roads at 16%, 25% and 28%, respectively.
Figure 3: Annual distribution of accidents at different types of roads

Figure 4: Percentage distribution of accidents by most vulnerable road users
A more detailed study shall be carried out for the accidents at the nine road types with more reference to the most vulnerable road users i.e. pedestrians and motorcyclists. Based on the average vehicle population from 2005 to 2008 (LTA, 2008), 18% of the total vehicle population are motorcycles. However, 54% of the accidents occur involved motorcycles. Motorcycles are of higher proportion substantially. Thus, there is a need to study them in greater detail.

5 ACCIDENTS INVOLVING VULNERABLE ROAD USERS

5.1 Motorcyclists

Age distribution and cause factors

Figure 6 shows the percentage distribution of age group of motorcyclists involved in accidents and segregated by types of roads. It can be observed that most of the motorcyclists involved in accidents belong to the youth (18 to 24 years old) or young adults (25 to 34 years old), with the youth having a higher proportion at an average of about 34%. Regardless of types of roads, these two groups of motorcyclists are of higher proportion in their involvement in accidents.

Table 1 show the various types of cause factors pertaining to the offending motorcyclists. It is observed that speed related factors are the major contributory factors, followed by motorcyclists failing to keep proper lookout. With the exception of junctions, speed related factors made up about 45% of the contributing factors for most of the roads, with the highest proportion at expressway slips and expressways, at 75% and 55%, respectively. The speed-related factors are factors such as illegal racing on the road, skidding due to excessive speed, exceeding road/vehicle speed limit and failing to have proper control. For both types of
junctons, “fail to keep a proper lookout” is the major contributing factor at 22% and 33%, followed by speed-related factors at about 16%. However, at signalised juncions, it is observed that these motorcyclists either disobey traffic signs/signals(33%) or fail to give way to traffic with right of way(14%), resulting in accident occurrences. For unsignalised juncions, failing to give way to traffic with right of way and overtaking are other contributing factors.

Figure 6: Percentage distribution of age group of motorcyclists involved in accidents for different types of roads

Table 1: Percentage distribution of motorcyclists cause factors

<table>
<thead>
<tr>
<th>Motorcyclist Cause factors</th>
<th>divided</th>
<th>Un-divided</th>
<th>One-way</th>
<th>Express-way slip</th>
<th>Other slip</th>
<th>Express-way</th>
<th>Signalised junctions</th>
<th>Un-signalised junctions</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn w/o due care</td>
<td>0.3</td>
<td>0.8</td>
<td>0.2</td>
<td>0.0</td>
<td>1.0</td>
<td>0.0</td>
<td>4.3</td>
<td>5.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Fail to give to traffic with right of way</td>
<td>1.3</td>
<td>2.4</td>
<td>1.7</td>
<td>0.7</td>
<td>6.6</td>
<td>0.5</td>
<td>14.3</td>
<td>19.3</td>
<td>4.0</td>
</tr>
<tr>
<td>Changing lane without due care</td>
<td>4.2</td>
<td>1.0</td>
<td>5.6</td>
<td>1.1</td>
<td>2.1</td>
<td>3.9</td>
<td>1.6</td>
<td>1.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Overtaking without due care</td>
<td>2.2</td>
<td>8.6</td>
<td>2.8</td>
<td>0.9</td>
<td>2.1</td>
<td>1.1</td>
<td>1.2</td>
<td>10.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Speed -related</td>
<td>46.4</td>
<td>43.5</td>
<td>39.7</td>
<td>74.9</td>
<td>44.8</td>
<td>55.4</td>
<td>15.5</td>
<td>17.6</td>
<td>44.2</td>
</tr>
<tr>
<td>Fail to keep proper lookout</td>
<td>34.7</td>
<td>32.5</td>
<td>38.2</td>
<td>14.3</td>
<td>30.9</td>
<td>26.4</td>
<td>22.6</td>
<td>33.1</td>
<td>29.2</td>
</tr>
<tr>
<td>Following too close to vehicle in front</td>
<td>4.9</td>
<td>4.6</td>
<td>4.8</td>
<td>2.3</td>
<td>5.9</td>
<td>6.8</td>
<td>1.9</td>
<td>4.6</td>
<td>4.8</td>
</tr>
<tr>
<td>Disobey traffic signs/signals</td>
<td>0.7</td>
<td>0.2</td>
<td>0.8</td>
<td>0.5</td>
<td>2.1</td>
<td>0.2</td>
<td>33.1</td>
<td>1.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Driving under the influence of alcohol</td>
<td>1.6</td>
<td>1.5</td>
<td>1.4</td>
<td>2.6</td>
<td>1.4</td>
<td>1.5</td>
<td>1.1</td>
<td>1.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Other factors</td>
<td>3.6</td>
<td>4.8</td>
<td>4.9</td>
<td>2.6</td>
<td>3.1</td>
<td>4.1</td>
<td>4.5</td>
<td>5.5</td>
<td>4.1</td>
</tr>
</tbody>
</table>

100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0
Types of accidents and vehicles involved in accidents

Table 2 shows the percentage distribution of motorcyclist accidents by types of accidents. It is observed that majority of these accidents involve motorcyclists self-skidding, especially at expressway slips and expressways, at the proportion of 69% and 41%, respectively. Rear-end accidents are other types of accidents that has high occurrence, especially at unsignalised junctions, slip roads and undivided roads. Among the junction accidents, about 40% are head-to-side accidents. Considering the types of vehicles that involved in accidents with motorcycles more frequently, cars and HGVs are of higher proportion (Table 3). Note that at undivided roads, proportion of HGVs involving in motorcycles accident are the highest at 17% and the lowest in terms of cars involvement (67%).

Table 2: Percentage distribution of motorcyclists accidents by types of accidents

<table>
<thead>
<tr>
<th>Types of accidents</th>
<th>divided</th>
<th>Undivided</th>
<th>One-way</th>
<th>Expressway slip</th>
<th>Other slip</th>
<th>Expressway</th>
<th>Signalised junction</th>
<th>Un-signalised junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self skidded</td>
<td>33</td>
<td>27</td>
<td>28</td>
<td>69</td>
<td>31</td>
<td>41</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Against stationary object/vehicle</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Rear end</td>
<td>14</td>
<td>19</td>
<td>11</td>
<td>5</td>
<td>18</td>
<td>12</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>Head-on</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Side-swap</td>
<td>14</td>
<td>4</td>
<td>14</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Junction accidents</td>
<td>5</td>
<td>13</td>
<td>3</td>
<td>1</td>
<td>11</td>
<td>46</td>
<td>46.2</td>
<td>45</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>6</td>
<td>6</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>17</td>
<td>19</td>
<td>19</td>
<td>12</td>
<td>24</td>
<td>19</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 3: Percentage distribution of vehicles types involved in motorcyclists accidents for different types of roads

<table>
<thead>
<tr>
<th>Types of vehicles</th>
<th>divided</th>
<th>undivided</th>
<th>One-way</th>
<th>Expressway slip</th>
<th>Other slip</th>
<th>Expressway</th>
<th>Signalised junction</th>
<th>Un-signalised junction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>cycle</td>
<td>2.3</td>
<td>1.8</td>
<td>2.8</td>
<td>0.7</td>
<td>5.6</td>
<td>0.0</td>
<td>1.9</td>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>car</td>
<td>73.1</td>
<td>66.8</td>
<td>73.9</td>
<td>69.5</td>
<td>76.6</td>
<td>72.7</td>
<td>75.2</td>
<td>71.6</td>
<td>72.7</td>
</tr>
<tr>
<td>LGV</td>
<td>8.2</td>
<td>9.0</td>
<td>8.8</td>
<td>10.9</td>
<td>6.3</td>
<td>7.6</td>
<td>7.8</td>
<td>9.4</td>
<td>8.3</td>
</tr>
<tr>
<td>bus</td>
<td>3.9</td>
<td>4.2</td>
<td>2.9</td>
<td>4.3</td>
<td>2.0</td>
<td>2.5</td>
<td>3.9</td>
<td>2.7</td>
<td>3.4</td>
</tr>
<tr>
<td>HGV</td>
<td>11.4</td>
<td>16.9</td>
<td>9.9</td>
<td>13.2</td>
<td>7.9</td>
<td>15.4</td>
<td>10.4</td>
<td>13.5</td>
<td>12.8</td>
</tr>
<tr>
<td>others</td>
<td>1.0</td>
<td>1.3</td>
<td>1.8</td>
<td>1.3</td>
<td>1.6</td>
<td>1.8</td>
<td>0.8</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Total%</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

5.2 Pedestrians

Taking into account that pedestrian accidents are of higher proportion in divided, undivided and one-way roads, it is necessary to have an understanding of the distribution of pedestrian movements on these types of roads. Table 4 shows that majority of the accidents occur when the pedestrians are crossing the road where there is no designated pedestrian crossing (about 20%) or crossing in front of or behind a vehicle (about 10% – 15%). For slip road, 50% of the accidents occurred when they are using the zebra crossing. At signalised
junctions, close to 50% occurred while they are crossing when green man is flashing while on unsignalised junctions, the accidents occurred while the pedestrians are crossing the roads without using any crossing.

Table 4: Percentage distribution of pedestrian movements on different types of roads

<table>
<thead>
<tr>
<th>Pedestrian movement</th>
<th>divided</th>
<th>Un-divided</th>
<th>One-way</th>
<th>Express-way slip</th>
<th>Other slip</th>
<th>Signalised junction</th>
<th>Unsignalised junction</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>On footpath</td>
<td>3.3</td>
<td>3.0</td>
<td>3.0</td>
<td>0.0</td>
<td>5.3</td>
<td>2.0</td>
<td>3.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Walk/Run with or against traffic</td>
<td>4.7</td>
<td>7.5</td>
<td>9.8</td>
<td>4.2</td>
<td>1.3</td>
<td>0.8</td>
<td>6.0</td>
<td>5.5</td>
</tr>
<tr>
<td>Stand on road</td>
<td>1.8</td>
<td>3.5</td>
<td>4.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>3.0</td>
<td>2.3</td>
</tr>
<tr>
<td>Working</td>
<td>1.3</td>
<td>2.1</td>
<td>1.5</td>
<td>8.3</td>
<td>0.0</td>
<td>0.2</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Attend to vehicle</td>
<td>0.4</td>
<td>0.6</td>
<td>1.4</td>
<td>4.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>At zebra crossing</td>
<td>1.3</td>
<td>4.0</td>
<td>1.5</td>
<td>12.5</td>
<td>52.6</td>
<td>1.1</td>
<td>1.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Crossing during green man at signalised crossing</td>
<td>6.5</td>
<td>1.3</td>
<td>2.8</td>
<td>0.0</td>
<td>0.0</td>
<td>41.6</td>
<td>1.1</td>
<td>10.6</td>
</tr>
<tr>
<td>Crossing during red man at signalised crossing</td>
<td>7.3</td>
<td>2.6</td>
<td>2.0</td>
<td>12.5</td>
<td>3.9</td>
<td>26.0</td>
<td>2.6</td>
<td>8.4</td>
</tr>
<tr>
<td>Unlawful within pedestrian crossing</td>
<td>13.3</td>
<td>5.4</td>
<td>9.3</td>
<td>12.5</td>
<td>6.6</td>
<td>4.5</td>
<td>6.8</td>
<td>8.7</td>
</tr>
<tr>
<td>No designated crossing</td>
<td>21.2</td>
<td>21.7</td>
<td>18.7</td>
<td>12.5</td>
<td>3.9</td>
<td>1.0</td>
<td>31.6</td>
<td>17.4</td>
</tr>
<tr>
<td>On divider or island</td>
<td>1.2</td>
<td>0.4</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>2.3</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>In front or behind stationary vehicles</td>
<td>9.2</td>
<td>14.4</td>
<td>10.1</td>
<td>8.3</td>
<td>0.0</td>
<td>0.8</td>
<td>3.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Others/unknown</td>
<td>28.6</td>
<td>33.5</td>
<td>35.6</td>
<td>25.0</td>
<td>26.3</td>
<td>19.6</td>
<td>38.3</td>
<td>29.7</td>
</tr>
<tr>
<td>Total percentage</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Figure 7 shows the percentage distribution of age group of pedestrians involved in accidents and segregated by types of roads. As observed from the graph, the proportion of children involved in accidents is much higher at divided and undivided roads, both at about 21%. A further investigation actually reveals that a substantial proportion of such accidents at divided and undivided roads are due to children crossing in front or behind vehicles which obstruct their views, at 25% and 28% respectively. The cause factors are children crossing heedless of traffic or crossing in front or behind a vehicle which obstructs view, or in the case when drivers are at fault, are drivers failing to keep a proper lookout or fail to give way at zebra crossing and disobey traffic lights (Table 5).
The proportion of youth involving in accidents are higher at expressway slips, other slips and signalised junctions at about 33%, 23% and 21% respectively. The proportion of elderly is highest at 23% at unsignalised junctions.

Figure 7: Percentage distribution of age group of injured pedestrians for different types of roads

Table 5: Percentage distribution of pedestrian and drivers cause factors for injured pedestrians <15 years old

<table>
<thead>
<tr>
<th>Pedestrian cause factors</th>
<th>% distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divided</td>
</tr>
<tr>
<td>Crossing heedless of traffic</td>
<td>38</td>
</tr>
<tr>
<td>Failure to use available crossing</td>
<td>16</td>
</tr>
<tr>
<td>Crossing within pedestrian crossing when red man lighted</td>
<td>17</td>
</tr>
<tr>
<td>Crossing in front or behind a vehicle which obstructs view</td>
<td>25</td>
</tr>
<tr>
<td>Playing on the road/carpark</td>
<td>0</td>
</tr>
<tr>
<td>Other pedestrian cause factors</td>
<td>5</td>
</tr>
<tr>
<td>Total percentage</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drivers cause factors</th>
<th>% distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Divided</td>
</tr>
<tr>
<td>Failing to give way at zebra crossing</td>
<td>2</td>
</tr>
<tr>
<td>Failing to keep a proper lookout</td>
<td>85</td>
</tr>
<tr>
<td>Disobeying traffic lights resulting in accidents with pedestrians</td>
<td>8</td>
</tr>
</tbody>
</table>
6 DISCUSSIONS

6.1 Motorcyclists

For motorcyclists, the high proportion of self-skidding accidents seems to be an indication that speed related factors are the major factors that lead to the occurrence of accidents, especially those that happen at expressways slips and expressways. As such, countermeasures involving reducing the speed or enhancing the driving environment to reduce the possibility of speed-related accidents are explored. The use of more speed cameras is one of the tools to consider, follow by enhancing skid resistance through use of high skid materials such as calcined bauxite. Majority of the motorcyclist accidents involved youth and young adults, ranging from age of 18 to 24 and 25 to 34 years old respectively. People of these age groups are often aggressive and reckless in their behaviour. More efforts in educating these groups are required to inculcate a good riding habit and to give them an understanding of the consequences of their behaviour.

6.2 Pedestrians

Based on the results, it is observed that pedestrians are of higher proportion in divided, undivided and one-way roads. This is not surprising given that the pedestrian volume is likely to be higher as these roads often pass through residential and recreational area. It is interesting to note that for these types of roads, especially the undivided and one-way roads, substantial proportion of accidents occurred when pedestrians are crossing in front of or behind vehicles. This is one of the factors that had been cited for accidents involving school children. On-street parking is quite predominant on these types of roads, as such, school children being shorter, are blocked from the view of the drivers. However, factors such as failure to use available crossing, crossing during red man and heedless of traffic are an indication of pedestrians’ lack of appreciation of where it would be safe to cross. As such, more education on road safety needs to be carried out to inculcate the correct behaviour of a pedestrian. Review of the adequacy of the existing crossing facilities near schools are also being carried out.

The results also show that substantial proportion of accidents occurred at zebra crossing at slip roads (50%). This could be attributed to the behaviour of both the pedestrians and the drivers where pedestrians do not look out for traffic while crossing the roads while the drivers do not keep a proper lookout when manoeuvring around the bend at the slip road. As such, new lane markings has been improvised on the roads before reaching such slip road to warn drivers to slow down as there is zebra crossing ahead.

7 CONCLUSIONS

The followings are the summary of the findings:

a) Majority of the accidents occur at divided roads and signalised junctions, followed by expressways and undivided roads. From categorisation of accidents based on most vulnerable road users, motorcyclist and pedestrians accidents occur most frequently.
b) Pedestrian accidents are of higher proportion in both divided, undivided and one-way roads. The accidents occurred when they cross without using any crossing facilities or crossing in front or behind a vehicle. This is especially predominant for accidents involving school children. For other types of roads such as slip roads, majority occur at zebra crossing.

c) Motorcyclist accidents are of higher proportion in expressway slips, expressways and unsignalised junction. With the exception from junctions, majority are speed-related accidents, involving youth and young adults. Accidents due to self skid occurred most frequently. In junction accidents, “disobey traffic signals” is the predominant cause factor for signalised junctions and accidents due to “fail to keep a proper lookout” are predominant for unsignalised junctions. Head-to-side accidents occur most frequently for both types of junctions. Cars and heavy good vehicles (HGV) involved in more accidents with motorcyclists on all types of roads, with the proportion of HGV higher in undivided roads.

8 ACKNOWLEDGEMENT

The raw data used for this analysis are obtained from Traffic Police Singapore. Any views and analyses in this paper are those from the authors and do not represent the views of the Traffic Police.

REFERENCE


STOPPING PROPENSITY AT RED LIGHTS IN SAUDI ARABIA

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ABSTRACT
More than 6450 people get killed and more than 36400 get injured due to traffic accidents in Saudi Arabia annually. Many of these are the victims of reckless driving behaviour like overspeeding and red-light crossing. Although red-light crossing cause more than 5% of traffic accidents in Saudi Arabia, no study has ever assessed the stopping propensity rate of drivers at red lights across Saudi Arabia. This study aims at determining this propensity so that traffic regulators and traffic police would prepare and execute their plans based on research findings. This current study will try to find out the rate of drivers crossing red lights in Saudi Arabia, if there are any differences between cities and towns across Saudi Arabia in terms of red-light crossing rate and to see if there are differences in red-light crossing occurrences between peak and off-peak times. Twenty four lighted intersections in seven different cities and towns across Saudi Arabia were observed for one hour during peak times and another hour during off-peak times in one direction. The total number of cars passing during each cycle was recorded as well as the number of cars passing red lights. Results showed that an astonishing 5.9% of drivers cross the intersections on red. Results also showed that there were significant differences in red-light crossing rate between the different cities/towns where this study took place. Moreover, results showed that more drivers tend to cross red lights during peak times than off-peak times. Finally, practical suggestions are made as to drop this high red-light crossing rate in order to improve traffic safety.

INTRODUCTION
Worldwide, more than 1.2 million people get killed due to traffic accidents annually according to World Health Organisation statistics. These deaths constitute around 2.1% of the global mortality rate. On top of that, more than 20 million people are injured annually due to traffic accidents. More than 85% of these losses occur in low and middle-income countries (Pedan et al., 2004). The situation in Saudi Arabia is not different. More than 6450 people get killed and more than 36400 get injured due to the approximately 486,000 accidents that happen annually in this country. Unfortunately and unlike many Western and some developing countries, the number of deaths and injuries due to traffic accidents is still increasing in Saudi Arabia as can be seen in Figure 1 where these numbers are given for the 15 years ending in 2008 (Traffic General Directorate, 1995-2009).
In fact, Saudi Arabia has one of the highest fatality risk levels in the world in terms of traffic accident fatalities with over 28 deaths per 100,000 people (Traffic General Directorate, 2009). The number of people killed on Saudi roads does not include those who died while receiving treatment at hospitals as the definition of a traffic fatality is limited to those who die at the accident scene (Al-Ghamdi, 2003).

Many Studies have assessed the state of traffic safety in Saudi Arabia (like Al-Ghamdi, 1999 & 2003; Al-Shammari et al., 2009; Al-Turky et al., 1997; Bendak 2005 & 2007; Koushki and Al-Ghadeer, 1992; Lee, 1986). All of these authors agreed that road safety is a very serious problem in Saudi Arabia despite the existing wide and well-maintained roads. They also agreed that this problem is partially due to the wrong behaviour of drivers and other road users. The most frequent cited and observed violations on the roads are overspeeding, red-light crossing, excessive lane changing, tailgating, not wearing seat belts and turning from the wrong lane.

For red-light running, two of these studies assessed drivers’ behaviour at intersections in the city of Riyadh. In the first study, Koushki and Al-Ghadeer (1992) assessed red-light stopping propensity at a sample of 12 intersections in Riyadh. The authors found that an average of 31 drivers ran the red light per hour at each intersection. They attributed this to drivers’ non-compliance with traffic regulations and signs.

In the second study, Al-Ghamdi (2003) analysed traffic accidents at urban intersections in Riyadh. The author’s objective was to analyse the number of such accidents to determine their characteristics so that remedies could be sought or at least future research could be suggested. A sample of 1774 reported accidents was collected in a systematic random manner for the period 1996-1998 (651 severe accidents (accidents resulting in at least one personal injury or fatality) and 1123 property-damage-only accidents).
probability and contingency table analyses were used to make inferences from data. The author found that improper driving behaviour is the primary cause of accident at signalized urban intersection in Riyadh; running a red light and failing to yield are the primary contributing causes.

Koushki and Al-Ghadeer (1992) and Al-Ghamdi (2003) specifically indicated that red light crossing is a common problem in this country. Official statistics also support this argument. These statistics show that 28,497 accidents happened in Saudi Arabia due to red-light crossing in 2008 or 5.75% of all accidents that occurred in Saudi Arabia during that year (Traffic General Directorate, 2009).

However, no study has ever assessed this stopping propensity across Saudi Arabia. This study aims at determining this propensity so that traffic regulators and traffic police would prepare and execute their plans based on scientific figures. This current study will try to answer the following questions:

1. How many drivers cross red lights in Saudi Arabia?
2. Are their differences between cities and towns across Saudi Arabia in terms of red-light crossing rate?
3. Are their differences in red-light crossing occurrences between peak and off-peak times?

METHODOLOGY

Red-light running can involve crossing the red signal at its on-set, anticipating the change to green and crossing at red before it changes or crossing in between. Since all of these cases are considered dangerous (and obviously illegal), this study involved assessing any red light crossing without taking into consideration the red light crossing type.

The most reliable and feasible method to collect data on red light crossing is through observing drivers’ behaviour at lighted intersections. Twenty four major intersections across seven cities/towns were selected for this purpose. The list of these intersections is given in Table 1 together with approximate population of each city/town (based on Al-Rabdi, 2004) knowing that the population in Saudi Arabia is close to 23 million citizens and expatriates.

As legal permits could not be solicited from relevant government agencies to install cameras at these intersections, the task of counting cars had to be done manually. A group of two observers was stationed near each designated intersection between October 2008 and May 2009. One of the two observers counted all cars passing on green or yellow and the other counted all cars passing on red in one direction during each light cycle for one hour during peak traffic time and one hour during off-peak time.

As the number of cars passing per hour at every intersection was estimated to be in hundreds, the sample size would be enough to obtain a reasonable effect size based on other observational studies like Bendak (2007) and Zhang et al. (2006). The data was analysed using the analysis of variance technique on SPSS version 16. Input variables were the timing (peak/off-peak), city/town and intersection. The dependent variable was the percentage of cars crossing the intersection on red.
Table 1: Intersections observed in the current study.

<table>
<thead>
<tr>
<th>City/Town</th>
<th>Approximate Population</th>
<th>Intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abqaiq</td>
<td>50,000</td>
<td>King Abdulaziz Rd – Jeddah St</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abu Bakr Rd – Othman St</td>
</tr>
<tr>
<td>Al-Kharj</td>
<td>200,000</td>
<td>King Abdullah Rd – king Abdulaziz Rd</td>
</tr>
<tr>
<td>Al-Khobar/Dammam</td>
<td>1,000,000</td>
<td>King Saud Rd – King Faisal Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Fahad Rd – Prince Mohammed Bin Fahad Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Faisal bin Fahad Rd – Corniche Rd</td>
</tr>
<tr>
<td>Hafr Al-Batin</td>
<td>250,000</td>
<td>King Faisal Rd – King Khalid Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Faisal Rd – King Abdulaziz Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Abdulaziz Rd – Prince Sultan Rd</td>
</tr>
<tr>
<td>Jeddah</td>
<td>3,000,000</td>
<td>Madinah Rd – Mohammed Bin Abdelaziz Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mohammed Bin Abdelaziz Rd – Majid Bin Abdelaziz Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Madina Rd – Sari St</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Fahad Rd – Palestine St</td>
</tr>
<tr>
<td>Madina</td>
<td>1,000,000</td>
<td>Jamiat St – Khalid Bin Al-Walid Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Abdullah Rd – Hajra St</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Omar Bin Al-Khattab Rd – 1st Ring Rd</td>
</tr>
<tr>
<td>Riyadh</td>
<td>5,000,000</td>
<td>King Abdullah Rd – Prince Turki (1st) St</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prince Sultan Rd – Prince Turki (1st) St</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olaya Rd – Prince Muhammed Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Abdulaziz Rd – Prince Sultan Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prince Turki (1st) St – Mecca Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Abdullah Rd – Khalid Bin Al-Walid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>King Fahad Rd – Prince Mohammad Bin Abdulaziz Rd</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prince Mohammad Bin Saud Rd – Abu Bakr Al-Siddiq Rd</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Total number of cars observed at intersections at peak and off-peak times as well as average red-light crossing rates in all seven cities/towns are given in Table 2.

Table 2: Number of cars observed and red-light crossing rates.

<table>
<thead>
<tr>
<th>City/Town</th>
<th>No. of cars observed during peak time</th>
<th>Peak time red-light crossing rate</th>
<th>No. of cars observed during off-peak time</th>
<th>Off-peak time red-light crossing %</th>
<th>Overall rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abqaiq</td>
<td>744</td>
<td>2.2%</td>
<td>564</td>
<td>1.8%</td>
<td>2%</td>
</tr>
<tr>
<td>Al-Kharj</td>
<td>613</td>
<td>6.1%</td>
<td>286</td>
<td>4.2%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Al-Khobar/Dammam</td>
<td>2646</td>
<td>2%</td>
<td>1378</td>
<td>1.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>Hafr Al-Batin</td>
<td>2936</td>
<td>4.9%</td>
<td>1146</td>
<td>5.4%</td>
<td>5%</td>
</tr>
<tr>
<td>Jeddah</td>
<td>3710</td>
<td>9.3%</td>
<td>2289</td>
<td>6.9%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Madinah</td>
<td>2325</td>
<td>3.4%</td>
<td>1167</td>
<td>2.7%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Riyadh</td>
<td>10708</td>
<td>8.2%</td>
<td>6597</td>
<td>5.4%</td>
<td>7.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>23682</strong></td>
<td><strong>6.5%</strong></td>
<td><strong>13428</strong></td>
<td><strong>4.9%</strong></td>
<td><strong>5.9%</strong></td>
</tr>
</tbody>
</table>
It is clear from Table 2 that an overall average red-light crossing rate of 5.9% in Saudi Arabia is surprising and alarming. This rate is considered much greater than many countries where fewer than 1 percent of drivers cross red lights (see, for example, Retting et al., 1999; Yang and Najm, 2007 and Porter and England, 2000). It is also clear from Table 2 that there are differences between the various cities/towns considered in this study. Analysis of variance results showed that these differences are statistically significant (p=0.00). A striking observation in this aspect is that the lowest rates were recorded in Al-Khobar/Dammam twin cities (1.8%) and Abqaiq (2%) which lie both in the Eastern Province of Saudi Arabia followed by Madinah (3.1%). Highest rates were recorded in the largest two cities in Saudi Arabia, namely Jeddah (8.4%) and Riyadh (7.1%). Both of these cities are famous for their congested traffic.

Moreover and as can be seen in Table 2, there were differences in red-light crossing rates between peak and off-peak times in all cities/towns considered in this study except Hafr Al-Batin. The difference was also clearly visible in the overall result where the crossing rate was 6.5% during peak times and 4.9 during off-peak times. Analysis of variance results showed that peak time red-light crossing rate was significantly greater than off-peak rate (p=0.02). The same result was found by Lum and Wong (2002) and Yang and Najm (2007). A possible reason for this difference is the higher degree of frustration experienced by drivers during peak hours where drivers usually have to wait many red-yellow-green light cycles till they pass the intersection due to congestion.

Results also showed that there were clear differences between the 24 intersections observed in this study in terms of red-light crossing rate. The highest rates were observed at the intersection of Madinah Road and Mohammed Bin Abdelaziz Road with a red-light crossing rate of 13.8% during peak time and 11.5% during off-peak time. The lowest rates were observed at the intersection of Abu Bakr Road and Othman Street with a red-light crossing rate of 1.5% during peak time and 1.2% during off-peak time. As expected, analysis of variance results showed that there were significant differences between the intersections observed (p=0.00).

There are a number of reasons that seem to be contributing to this behaviour of ignoring red lights. First, drivers do not think that there is high probability of their red-light crossing being detected by traffic police and, consequently, of their receiving an infringement ticket. Even if they are detected by traffic police, it looks like the current penalty system might not be deterring some drivers from such a behaviour. To investigate this issue further, the annual number of red-light crossing infringement tickets issued in the last few years was investigated. It was found that the ratio of this type of tickets to the total number of traffic tickets issued in Saudi Arabia has increased from around 5% in 2003 to close to 7.2% in 2008 (Traffic General Directorate, 2004-2009). Yet, this 7.2% of traffic tickets (representing around 700,000 tickets) are still not deterring many drivers from crossing red lights. This raises doubts about the effectiveness and relevance of the traffic laws enforcement system, including traffic infringement tickets in deterring red-light crossing.

A second reason that is likely to be contributing to this behaviour is underestimation of the risk involved by drivers crossing the red light as well as other aggressive violations of traffic laws like overspeeding and tailgating. Public awareness campaigns are likely to improve risk perception among drivers and other road users (see, for example, Fletcher et al., 2007). Although many traffic awareness campaigns are conducted annually by government...
agencies and non-government organisations, the issue of red-light crossing has not been given
enough attention in these campaigns and public tolerance for red-light crossing looks still
unacceptably high.

A third contributing reason might be the inadequate traffic signal cycles. Almost all of
these cycles are fixed and insensitive to traffic volumes. Many drivers are often stopped when
there is no traffic using the opposite arms. This is likely to increase the level of frustration
among drivers, especially during peak hours, and increases the risk of drivers crossing red
lights to save time and avoid further delays.

CONCLUSIONS
Drivers crossing lighted intersections on red are common in Saudi Arabia. They cause more
than 5% of all accidents on Saudi roads. This study was the first comprehensive one ever to
assess this issue by observing drivers at 24 observing stations (intersections) in seven
cities/towns across Saudi Arabia.

Results showed that 5.9% of the more than 37,000 cars observed crossed the
intersection on red. Besides this, there were large and significant differences between
cities/towns in terms of red-light crossing. Results also showed that drivers tend to cross red
lights during peak times more often than during off-peak times. These results

Results of the current study clearly indicate that measures taken to this date to combat
the problem of red-light crossing were not enough. Accordingly, it is recommended here that
the traffic law enforcement system should be evaluated and the punishment system should be
tightened. Among the enforcement system, it is strongly recommended that red-light cameras
be installed quickly at lighted intersections across Saudi Arabia in order to combat this
problem. These cameras are proven to be effective in curbing red-light crossing (Datta et al.,
2000) specially when supported by an adequate level of penalty (Wong et al., 2008) even at
intersections with no cameras (Retting et al., 1999). Also, specific public awareness
campaigns should target this red-light crossing problem in order to improve public awareness
and risk perception.

Results also indicate that frustration plays an important role in making this problem
worse as more drivers tend to cross red lights during peak times, likely out of frustration, than
during off-peak times. Installing “intelligent traffic light system” might one solution for this
problem where the duration of green is somehow proportional to the traffic volume crossing
from each intersection side. This system has been trialled previously and was found to have
contributed in lowering drivers’ frustration and curbing red-light crossing (Retting et al.,
2008).

REFERENCES
Analysis and Prevention, Vol. 35, pp. 717-724

Solutions. King Abdulaziz City for Science and Technology (KACST), ISBN 9-54-724-9960,
Riyadh.


Vulnerable Road User Safety Across Several International Regions
Brian Fildes, Monash University, Accident Research Centre, Europe, Australia/Italy

Dubai Pedestrian Safety & Mobility Action Plan
Saad Al Asady, Roads & Transport Authority, Dubai, United Arab Emirates

Comparative Cross-Cultural Analyses on Road Safety among Vulnerable Road Users
Ernest Agyemang, NTNU, Norway/University of Ghana, Ghana

Bicycle Helmets, Risk Compensation and Cyclist Types
Aslak Fyhri, Institute of Transport Economics, Norway

Criteria for Age Based Design of Active Vehicle Safety Systems
Eckart Hauck, Aachen University, Germany
VULNERABLE ROAD USER SAFETY ACROSS SEVERAL INTERNATIONAL REGIONS

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ABSTRACT

The study set out to compare crash and injury patterns of Vulnerable Road Users across a number of different countries and databases to illustrate relative outcomes in different regions. Several analyses of crash and casualty crash patterns were undertaken using real-world crash databases from a number of different countries. The factors examined included the type of vulnerable road user, the vehicle involved, the primary crash cause, age of the road user, injury outcome (fatal or casualty), crash location and single or multi-vehicle collision. The findings from this study highlighted emerging and severe road crash problems for society currently not being addressed in existing safety initiatives by governments or vehicle manufacturers in these regions. A number of potential solutions to these problems including engineering countermeasures for vehicles and road infrastructure, greater use of protective equipment for riders, enhanced police enforcement efforts and technologies, and improved training and licensing practices. Public policy response to this growing epidemic in developing countries has been muted at national and international levels and policy makers need to recognise this growing problem as a public health crisis and design appropriate policy responses. With growing usage of VRU transport in developing countries, this burden is expected to become even larger in the years ahead in these regions without urgent attention.

1 INTRODUCTION

Safety experts typically define Vulnerable Road Users as either those who are either inexperience or fragility (i.e.; children or seniors) or those who are more exposed (less protected) to injury in the event of a crash, such as pedestrians, motor cyclists or bicyclists. It is generally accepted that they are more “vulnerable” compared to car, small and large trucks and buses because they are less protected because of their mode of transport or personal characteristics. The protection of vulnerable road users is a critical area of road safety given their numbers on the road and the particular risks associated with these modes of travel.

1.1 Extent of the Problem

Death and casualties to Vulnerable Road Users (VRU) represents a sizeable annual trauma burden internationally. It is claimed that of the 43,000 people killed and more than three million casualties each year in Europe, VRUs, such as child cyclists and the elderly, are the most at risk[1]. In Australia, of the 1616 deaths from road accidents in 2007, approximately 30 percent comprised motorcyclists, pedestrians and bicyclists[2].

The proportions of road deaths in Europe in 2005[9] is shown in Figure 1 below. While car deaths accounted for roughly half of these for the whole population, the total among Vulnerable Road Users was only just slightly less. Noticeably, pedestrians made up around 17% of those, motorcycles 12% and among 18 to 25 year olds, moped crashes were especially noteworthy. Among the Southern SEC Belt countries, France and Italy reportedly accounted for approximately two-thirds of the deaths in 2005 in this region[6].
In Italy, there are 97 deaths per million inhabitants, and slightly above the national average for Europe of 95 deaths per million inhabitants.\textsuperscript{3,4,5} This is in spite of the fact that the Italian government adopted a National Plan for road safety in 2000 that included a stated objective to reduce the road toll by 40\% by 2010 with a particular focus on Vulnerable Road Users.\textsuperscript{6}

**Table 1: VRU killed in road crashes in Southern SEC Belt countries**\textsuperscript{6}

<table>
<thead>
<tr>
<th></th>
<th>Pedestrians</th>
<th>Cyclists</th>
<th>PTW</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>866</td>
<td>223</td>
<td>1,450</td>
<td>2,539</td>
</tr>
<tr>
<td>Greece</td>
<td>279</td>
<td>396</td>
<td>14</td>
<td>689</td>
</tr>
<tr>
<td>Italy</td>
<td>1,188</td>
<td>364</td>
<td>1,191</td>
<td>2,743</td>
</tr>
<tr>
<td>Spain</td>
<td>776</td>
<td>96</td>
<td>784</td>
<td>1,656</td>
</tr>
<tr>
<td>Portugal</td>
<td>339</td>
<td>57</td>
<td>359</td>
<td>755</td>
</tr>
<tr>
<td>Total</td>
<td>3,448</td>
<td>1,136</td>
<td>3,798</td>
<td>8,382</td>
</tr>
</tbody>
</table>

**1.2 Developing Countries**

In developing countries, the figures are even worse. For instance, in Thailand, it is claimed that most of the 13,000 deaths and more than one million casualties from road accidents each year, an overwhelming majority involve motorcyclists, cyclists and pedestrians\textsuperscript{5}.

Traffic deaths and casualties in Malaysia have also been growing over recent years. In 2005, the road toll accounted for 6,200 deaths and 328,000 casualty crashes each year\textsuperscript{7}. Of the reported crashes, more than 77 percent of them involved VRUs such as motorcyclists (66\%), pedestrians (8\%) and bicycle riders (3.5\%). The total number of deaths and casualties in Malaysia is shown in Figure 2 from 1974 to 2005, associated with a 250 percent rise in the amount of traffic. As most of these crashes involved VRU, there would also have been more than a 3-fold increase in VRU deaths and crashes over this period.
1.3 Growing Societal Problem

Furthermore, the problem is not getting better. Growth in the number of users and their vulnerability suggests the numbers of VRUs is growing rapidly worldwide. Figure 3 shows that as the numbers of motorcycles has grown in Sweden, so too has the number of motorcyclists killed and seriously casualty in road accidents.[8]

1.4 Objective

This paper sets out to examine these trends in more detail to illustrate differences in crash patterns, types of crashes and crash victims in Italy, Malaysia and Australia (different countries and continents) to show the influence of culture and development across these regions. It is hoped that this will help identify potential road safety priorities, countermeasures and safety initiatives, of relevance in these differing regions. These countries were chosen as they represent a good contrast in cultures and for which representative data were available.
2 DATA ANALYSIS

Crash data were available for analysis in these three countries and continents and individual analyses were performed on these data by representatives of each country, using a common analysis format and crash data period. The data period for the years 2005 to 2008 approximately was selected for analysis and reported separately by each country as an average proportion for each region. An overall analysis was then assembled, comparing each of the three countries to highlight similarities and differences.

2.1 Analysis Procedure

Police-based mass databases were available for analysis from the ISTAT database in Italy, the M-ROADS database in Malaysia, and from the collection of five Australian states of police data in Victoria, New South Wales, Queensland, South Australia and Western Australia (95% of the population). These three databases comprise crash records from 3 continents were expected to reveal different patterns of crashes and injury outcomes for VRU from varying levels and types of motorization.

Each analysis focused on a number of common variables, including (i) outcome severity [killed or casualty crash], (ii) type of vehicle involved [motorcycle, pedestrian, bicycle, passenger car, and bus or truck], (iii) area of the crash location [urban/rural], (iv) who hit who, and (v) age group of the crash victim [all ages and young drivers/riders]. Different levels of risk among fatalities and all injured were also computed for the various Vulnerable Road User groups in Italy, Malaysia and Australia using the numbers of victims per registered vehicle for further comparison.

These analyses were predominantly crash-based and inclusion criteria were applied across regions for consistency. Where an accident occurred between a passenger car and a motorcycle for instance, each was counted twice, one for the passenger car, and again for the motorcycle. If the accident was between two passenger cars, however, it was only counted once. However, for the analyses of which vehicle hit which road user, all the vehicles have been considered. The risk analyses, though, were person-based as is the conventional practice for computing these figures.

The number and percentage of crashes included those involving both a fatal and casualty crash outcome as determined by the attending police officer. Fatal crashes were defined as those where at least one of the crash victims was killed, while casualty crashes comprised those crashes where no one was killed but where at least one victim was recorded as casualty. It was expected that fatal crashes would differ from those where someone was casualty as this often reflects different levels of crash severity. No distinction was made between severe and moderate injuries in this analysis to keep the findings manageable.

In addition, no attempt was made to evaluate these differences statistically because of the sizeable number of cases involved across each of the regions. Hence, the finding obtained comprised a purely descriptive analysis of differences between these three countries and continents. Analysing large databases statistically such as those contained in this analysis across different regions can be problematic. The analysis, however, is useful as an overview document and helpful in setting the research agenda in these regions.

3 RESULTS

3.1 Proportion of VRU Crashes

The first analysis was to simply compare the proportion of VRU crashes by each region for both fatal and casualty crashes, shown in Table 2.
Table 2: Proportion of crashes by road user type, country and outcome severity

<table>
<thead>
<tr>
<th>Road User Type</th>
<th>Italy</th>
<th>Malaysia</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
<td>Casualty</td>
<td>Fatal</td>
</tr>
<tr>
<td>Trucks &amp; buses</td>
<td>15.7%</td>
<td>9.3%</td>
<td>6.9%</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>49.7%</td>
<td>56.2%</td>
<td>26.9%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>9.3%</td>
<td>5.6%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>15.8%</td>
<td>14.8%</td>
<td>50.7%</td>
</tr>
<tr>
<td>Mopeds</td>
<td>5.1%</td>
<td>10.0%</td>
<td></td>
</tr>
<tr>
<td>Bicycles</td>
<td>4.4%</td>
<td>4.0%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Total Proportion</td>
<td>2.1%</td>
<td>97.9%</td>
<td>7.4%</td>
</tr>
</tbody>
</table>

Data on moped crashes was reported separately to motorcycles for the Italian database but included together with motorcycles for both Malaysia and Australia. Most strikingly, Vulnerable Road User crashes varied across these three regions; from as low as 14-16% for fatal and casualty cases in Australia to a high of 66-50% for Malaysian cases. Passenger vehicle crashes were the predominant vehicle type among Australian fatal and casualty crashes, while motorcycles (including mopeds) predominated among Malaysian casualties. Italian statistics were somewhere in-between these two extremes. To some degree, these findings most likely reflects differences in vehicle and VRU exposure rates across the three regions, although the higher proportion of fatalities among Malaysian casualty crashes (7.4% vs. 2.1% and 3.4%) might suggests a higher risk among VRU over other forms of transport or by differences in data recording across the three regions which is examined in later analyses.

3.2 Differences in crash region

Differences in the proportion of crashes across urban and rural crash locations are illustrated in Table 3. These figures are for fatal and casualty crash outcomes combined.

Table 3: Proportion of crashes by road user type, country and urban/rural environment

<table>
<thead>
<tr>
<th>Road User Type</th>
<th>Italy</th>
<th>Malaysia</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban</td>
<td>Rural</td>
<td>Urban</td>
</tr>
<tr>
<td>Trucks &amp; buses</td>
<td>6.8%</td>
<td>15.6%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>53.1%</td>
<td>62.9%</td>
<td>41.3%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>7.1%</td>
<td>2.3%</td>
<td>6.3%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>16.4%</td>
<td>11.2%</td>
<td>42.9%</td>
</tr>
<tr>
<td>Mopeds</td>
<td>12.0%</td>
<td>5.2%</td>
<td></td>
</tr>
<tr>
<td>Bicycles</td>
<td>4.6%</td>
<td>2.8%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Totals</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Total Proportion</td>
<td>69.3%</td>
<td>30.7%</td>
<td>23%</td>
</tr>
</tbody>
</table>

The proportions of urban and rural crash location varied considerably across the three regions; urban crashes were most frequent in Australia (82.3%) and Italy (69.3%) while rural crash locations were more frequent in Malaysia (77%). The proportion of VRU crashes also differed across the regions where the proportion of VRU urban crashes varied from 51% in Malaysia, 40.1% in Italy to 27.4% in Australia. While not shown here, the proportion of fatal crashes in rural areas was higher for Malaysia (7.4%) than either Australia (5.6%) or Italy.
(4.4%) reflecting again the possible the increased vulnerability and risks of VRUs in these higher speed locations and/or differences in recording criteria.

3.3 Differences between Single and Multiple Collisions

Table 4: Proportion of crashes by road user type, country and single/multiple vehicles

<table>
<thead>
<tr>
<th>Road User Type</th>
<th>Italy Single</th>
<th>Italy Multiple</th>
<th>Malaysia Single</th>
<th>Malaysia Multiple</th>
<th>Australia Single</th>
<th>Australia Multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; buses</td>
<td>8.3%</td>
<td>9.8%</td>
<td>10.0%</td>
<td>9.5%</td>
<td>7.3%</td>
<td>7.4%</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>61.5%</td>
<td>54.8%</td>
<td>42.5%</td>
<td>39.3%</td>
<td>68.8%</td>
<td>79.7%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0%</td>
<td>7.0%</td>
<td>0%</td>
<td>6.8%</td>
<td>0%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>17.0%</td>
<td>14.3%</td>
<td>45.9%</td>
<td>42.5%</td>
<td>21.4%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Mopeds</td>
<td>10.2%</td>
<td>9.8%</td>
<td>0%</td>
<td>21.4%</td>
<td>4.3%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Bicycles</td>
<td>3.0%</td>
<td>4.3%</td>
<td>1.6%</td>
<td>1.9%</td>
<td>2.4%</td>
<td>3.0%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Total Proportion</td>
<td>18.9%</td>
<td>81.1%</td>
<td>20.7%</td>
<td>79.3%</td>
<td>13.5%</td>
<td>86.5%</td>
</tr>
</tbody>
</table>

The proportions of single and multiple collisions were quite similar across the regions, ranging from 13.5% urban in Australia, 18.9% in Italy, and 20.7% in Malaysia. There were differences, however, in the proportions of VRU where Malaysia reported almost half VRU crashes (47.5%) while for Italy the figure was 30.2% and Australia 23.8%. Clearly, the differences in crash location is having some effect here (rural crashes tend to be at higher severity than urban ones) as well as any increased vulnerability.

3.4 Collision Configurations

The next series of analyses focuses on “who” collides with “who” for the fatal and all casualty cases combined in multi-vehicle collisions.

Table 5: Proportion of multi-vehicle fatal crashes by road user type, Italy

<table>
<thead>
<tr>
<th>Multi-Vehicle Crashes</th>
<th>Trucks &amp; Buses</th>
<th>Passenger Vehicles</th>
<th>Peds</th>
<th>Motorcycles</th>
<th>Mopeds</th>
<th>Bicycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; Buses</td>
<td>1.1%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>8.7%</td>
<td>39.3%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0.9%</td>
<td>7.4%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>1.8%</td>
<td>17.7%</td>
<td>1.3%</td>
<td>0.8%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mopeds</td>
<td>1.1%</td>
<td>12.3%</td>
<td>0.9%</td>
<td>0.8%</td>
<td>0.4%</td>
<td>-</td>
</tr>
<tr>
<td>Bicycles</td>
<td>0.6%</td>
<td>4.1%</td>
<td>0.1%</td>
<td>0.4%</td>
<td>0.3%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Totals</td>
<td>14.2%</td>
<td>80.7%</td>
<td>2.2%</td>
<td>2.0%</td>
<td>0.7%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

In the Italian analysis shown in Table 5, passenger vehicle collisions with all other partners was most predominate, accounting for almost 81% of all multi-vehicle collisions. The most common crash partner for a passenger vehicle collision was another passenger vehicle (around 40% of all cases). Multi-vehicle VRU crashes in Italy accounted for roughly 50% of
these cases, the majority being with a passenger vehicle, a truck or a bus (45.8%). Not surprising, two-wheel vehicles were the principle VRU vehicle type in these collisions with passenger vehicles (20% for motorcycles and 13% for mopeds). Only a very small 5% of these cases involved a VRU striking another VRU.

Table 6: Proportion of multi-vehicle crashes by road user type, Malaysia

<table>
<thead>
<tr>
<th>Multi-Vehicle Crashes</th>
<th>Trucks &amp; Buses</th>
<th>Passenger Vehicles</th>
<th>Peds</th>
<th>Motor Cycles</th>
<th>Bicycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; Buses</td>
<td>6.8%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Passenger vehicle</td>
<td>3.3%</td>
<td>28.7%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0.6%</td>
<td>2.5%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Motorcycles &amp; mopeds</td>
<td>4.6%</td>
<td>17.0%</td>
<td>1.5%</td>
<td>32.1%</td>
<td>-</td>
</tr>
<tr>
<td>Bicycles</td>
<td>0.2%</td>
<td>0.9%</td>
<td>0.1%</td>
<td>0.6%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Totals</td>
<td>15.5%</td>
<td>49.1%</td>
<td>1.6%</td>
<td>32.7%</td>
<td>1.2%</td>
</tr>
</tbody>
</table>

In Malaysia, the situation is quite different as shown in Table 6. Here, the proportion of passenger vehicle crashes is less than 50% and the most common collision partnership is not with passenger vehicles but between motorcycles and mopeds with each other (32.1%). VRU collisions with trucks, buses and passenger vehicles account for over 61% of all multiple vehicle crashes and more than 35% of crashes among themselves. This no doubt can be explained to some degree by the high level of exposure (47% of vehicle registrations in 2007\[10\]) but also predictably from the higher risk that VRU have to being casualty when involved in a crash.

Table 7: Proportion of multi-vehicle fatal crashes by road user type, Australia

<table>
<thead>
<tr>
<th>Multi-Vehicle Crashes</th>
<th>Trucks &amp; Buses</th>
<th>Passenger Vehicles</th>
<th>Peds</th>
<th>Motor Cycles</th>
<th>Bicycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; Buses</td>
<td>1.0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>9.2%</td>
<td>62.5%</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>0.9%</td>
<td>9.5%</td>
<td>0%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Motorcycles &amp; mopeds</td>
<td>0.6%</td>
<td>6.9%</td>
<td>0.2%</td>
<td>0.5%</td>
<td>-</td>
</tr>
<tr>
<td>Bicycles</td>
<td>0.9%</td>
<td>7.4%</td>
<td>0.2%</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Totals</td>
<td>12.6%</td>
<td>86.3%</td>
<td>0.4%</td>
<td>0.6%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

The third and final analysis of who-hits-who relates to crashes in Australia in Table 7. Clearly, practically all multiple vehicle collisions in this region involved passenger vehicles and trucks (99%). Vulnerable Road User collisions accounted for 27.3% of these crashes most of which were with a passenger vehicle. Pedestrians and cyclists seemed to be the most common VRU killed or seriously casualty in these figures, while motorcycles were involved in only 8.2% of these crashes. Given that motorcycles in Australia comprise around 3% of the total motor vehicles registered in 2006\[11\], this also confirms their vulnerability and potential over-involvement rates.
3.5 Relative Risk

An analysis of the relative risk by mode of travel per registered vehicle was also conducted in the three regions as shown in Figures 4 and 5 below. It was not possible to do a comparative analysis for pedestrians and cyclists as the relative risk denominator would have been quite different and unknown. Rate per registered vehicle was chosen as the only available measure in all three countries. It would also have been interesting to compare the rate by distance travelled but unfortunately, these exposure figures were not available in each of these countries.

These figures show that the risk of being killed in a crash is much higher for motorcyclists than for vehicle occupants (more than 4 times on average in Malaysia and Australia and about double in Italy). Comparisons across these regions further shows higher crash rates in Malaysia for both motorcycle (plus 30%) and for all vehicle crashes (plus 56%) than in Australia. Clearly, these figures illustrate a higher risk of crashing for all motorists in the Asian region, but especially for vulnerable motorcyclists.

Interestingly, the fatal crash rate for motorcycles in Italy is only around one-third that of Australia and Malaysia which seems a little strange. However, it should be noted that the number of motorcycles in Italy comprises around two-thirds mopeds (less than 50cc units) while in Malaysia and Australia, the figures relate to predominantly full motorcycles. On closer examination, mopeds in Italy are predominantly used in urban areas where crash speeds are lower and their fatal crash rate is only one-sixth that of motorcycles. After correcting for this, the fatality rate for Italian motorcycles is close to that of the other two countries where motorcycles are commonly use on open roads and crash at higher speeds.

Of interest also are the proportional differences of fatal crashes involving motorcycles and cars across the three countries. In Malaysia in 2007, 75% of these vehicle-type fatalities involved motorcycles (only one-quarter were car occupants), while in Italy, the equivalent figures for motorcycles was 45% and 17% in Australia. These clearly reflect differences in the frequency of use of motorcycles in these regions and the inherent risk these VRU riders face.

It should also be noted that the real risk in the use of motorcycles in all these regions is somewhat masked by the exposure measure used (per 10,000 registered vehicles). In Europe for example, motorcyclists are 18 times more likely to be killed than car occupants when measured on a distance travelled (per kilometer) basis. It would have been preferable to have used a distance travelled measure for this analysis too had they been available as per registered vehicle ignores the real usage rates of these vehicles.
3.6 Age Group

The final analysis of the VRU figures across the three regions was to compare the overall findings for all ages with those of young drivers and riders. The fatality proportions are shown in Table 8 and the equivalent all injured proportions in Table 9.

### Table 8: Proportion of fatal injured by road user type and country

<table>
<thead>
<tr>
<th>Road User Type</th>
<th>Italy All ages</th>
<th>Italy 0-25yrs</th>
<th>Malaysia All ages</th>
<th>Malaysia 0-25yrs</th>
<th>Australia All ages</th>
<th>Australia 0-25yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; buses</td>
<td>5.9%</td>
<td>2.4%</td>
<td>6.9%</td>
<td>3.5%</td>
<td>11.7%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>47.5%</td>
<td>56.1%</td>
<td>26.9%</td>
<td>25.3%</td>
<td>72.0%</td>
<td>65.0%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>13.1%</td>
<td>4.9%</td>
<td>12.0%</td>
<td>8.3%</td>
<td>7.3%</td>
<td>11.7%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>20.7%</td>
<td>22.5%</td>
<td>50.7%</td>
<td>60.6%</td>
<td>7.7%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Mopeds</td>
<td>6.6%</td>
<td>11.7%</td>
<td>5.0%</td>
<td>10.6%</td>
<td>7.7%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Bicycles</td>
<td>6.0%</td>
<td>2.5%</td>
<td>3.4%</td>
<td>2.3%</td>
<td>1.3%</td>
<td>2.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

### Table 9: Proportion of all injured by road user type and country

<table>
<thead>
<tr>
<th>Road User Type</th>
<th>Italy All ages</th>
<th>Italy 0-25yrs</th>
<th>Malaysia All ages</th>
<th>Malaysia 0-25yrs</th>
<th>Australia All ages</th>
<th>Australia 0-25yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks &amp; buses</td>
<td>4.3%</td>
<td>2.2%</td>
<td>9.8%</td>
<td>3.3%</td>
<td>7.3%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Passenger vehicles</td>
<td>57.6%</td>
<td>55.2%</td>
<td>41.0%</td>
<td>28.2%</td>
<td>78.5%</td>
<td>84.6%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>6.4%</td>
<td>4.6%</td>
<td>4.8%</td>
<td>6.8%</td>
<td>4.7%</td>
<td>4.3%</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>16.6%</td>
<td>13.9%</td>
<td>42.6%</td>
<td>59.4%</td>
<td>6.5%</td>
<td>3.9%</td>
</tr>
<tr>
<td>Mopeds</td>
<td>10.9%</td>
<td>21.0%</td>
<td>42.6%</td>
<td>59.4%</td>
<td>6.5%</td>
<td>3.9%</td>
</tr>
<tr>
<td>Bicycles</td>
<td>4.2%</td>
<td>3.1%</td>
<td>1.7%</td>
<td>2.4%</td>
<td>3.0%</td>
<td>2.7%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The figures for fatal injured in Australia and Italy show higher proportion of car and truck deaths for all and younger road users than for Malaysia as reported earlier, with slightly fewer young driver occupant deaths than those for all ages, apart for Italy. However, there was a noticeably higher proportion of deaths among younger motor cyclists in all three regions, irrespective of differences in the level of exposure. Clearly, preventing motorcycle fatalities must be a priority in all these two regions, as well as for young riders of mopeds in Italy.

Pedestrian death proportions were also quite high in all three countries. Moreover, it was noticeably higher among all ages than younger road users in Italy and Malaysia (yet opposite in Australia). It has been reported previously that the risk of a pedestrian death per population is higher among the elderly\textsuperscript{[17]} which would help to explain this phenomenon. The different finding in Australia is difficult to explain except to note that this difference is not so apparent among all injured, suggesting younger pedestrian crashes occur at higher speeds in this country - speed limits in urban areas in Australia are among the highest in the world\textsuperscript{[18]}. The proportions of pedestrian deaths were higher than for the all injured in the three regions, confirming an increased vulnerability for these unprotected road users.

While there were some minor differences in the proportions between fatal and all injury percentages, the trends nevertheless, were quite similar.
4 GENERAL DISCUSSION

This study set out to examine trends in Vulnerable Road User casualty crash involvement in more in Italy, Malaysia and Australia (different countries and continents) to examine differences in crash patterns, types of crashes and crash configurations in detail to show the influence of culture, development and transportation patterns across these regions. The analyses performed highlighted some very interesting findings.

4.1 VRU Crashes

The proportion of Vulnerable Road User crashes varied considerably across these three regions. The lowest involvement rate was in Australia where VRUs accounted for just 14 and 16% of fatal and all casualty cases, compared to Malaysia where the proportion was much higher (66% of fatal crashes and 50% for all injured). Figures for Italy were somewhere in-between these two extremes at around one-third of all fatalities and overall casualties. It was argued earlier that these finding may reflects differences in vehicle and VRU exposure rates across the three regions (there is a greater proportion of motorcycle and moped vehicles in Malaysia, compared to Italy and Australia). In 2007, for example, it was claimed that there were 7.9 million motorcycle registrations in Malaysia or 47.3% of total vehicle registrations\[10\]. In addition, there was also a 4-times higher risk of a fatality over a car occupant in Malaysia and a sizeable increase in risk over equivalent motorcyclist crashes in Italy.

This analysis was unable to clarify more on these effects. It could reflect a different motorcycle population in Malaysia over the other two countries (there tends to be higher proportions of mopeds or smaller motorcycles used in this region) or other traffic or behavioural differences. A study modeling motorcycle and non-motorcycle flows entering an intersection showed an increase in motorcycle crashes as traffic density increased\[13\]. They also noted that approach speed, lane width, number of lanes, shoulder width and land use were also found to be statistically associated with these crashes. It was also argued by the Director of MIROS\[10\] that transportation policies in Malaysia have a culture that generally does not put road safety first. Hence, there is a need to instill in motorists and professionals in the region a greater sense of the importance of safety and safe behaviour on their roads.

4.2 Urban and Rural Locations

There were also noticeable differences in where these VRU crashes happened across the three regions. In Australia and Italy, there was a greater propensity for VRU collisions in urban areas (82.3% and 60.3%) than in Malaysia (23%). This is somewhat surprising given the urban density in Malaysia in towns like Kuala Lumpur. Moreover, there was a high incidence of single vehicle crashes in Malaysia over the other two countries, although there was a surprisingly low number of multiple motorcycle crashes in Australia (roughly 20% to that of single vehicle crashes in this region). As the split in single and multiple vehicle crashes in both Italy and Malaysia was closer to 50%, these findings are difficult to explain without further in-depth analysis of the crashes to pinpoint possible causes. Nevertheless, these findings have ramifications for where priority setting for intervention should lie.

Pedestrian collisions in urban and rural areas are also of concern in all three regions where these crashes comprise up to 17% of all fatalities. Of special note, roughly one-third to one-half of all these crash types occurred in rural areas and predominantly involved a collision with a passenger vehicle which is quite alarming, given that pedestrian movements in rural areas tend to be less frequent than in urban areas. Many of these people have variable road crossing skills, especially young children, the elderly and those with disabilities. Clearly, more needs to be done to reduce their numbers in these locations. From observation, it seems
that failure on the part of motorists to pay greater respect to pedestrian movement may be part of this level of trauma but so too, the need for pedestrians to cross and walk on roads at safe locations (e.g., traffic light intersections or statutory road crossing points) where motorists are likely to be more aware of their presence.

4.3 Collision Partner

The analysis examined the collision partner of VRUs to throw light on any anomalies across these regions. As noted previously, passenger vehicles and trucks and buses were the predominant collision partner with VRUs in Italy (95%) and Australia (99%). These findings point to the need for improved vehicle technology such as slower speeds, enhance braking, or better pedestrian protection of vehicles, to address this problem. Surprisingly, motorcycle to motorcycle collisions were quite prevalent in Malaysia (around one-third of all collision partners) which is somewhat surprising and difficult to explain by increase exposure alone. It does suggest that motorcycle riders need to be more aware of other vehicles, especially other motorcycles on roads in Malaysia and perhaps the need for improved braking performance, such as ABS for these units. Recent evidence suggests that this technology has the possibility of greatly reducing the number of these crashes\[8\] although it is not clear of their effectiveness specifically against other 2-wheeled units.

4.4 Age Effects

The representativeness of younger VRUs was examined in this analysis across the three countries. In Australia, there were fewer young driver deaths than for all ages but a higher proportion among younger motorcyclists and pedestrians. In Malaysia and Italy, there were higher proportions of motorcycle deaths and injured than in Australia, reflecting their higher exposure in these two countries. However, young motorcycle riders in Australia were injured proportionally less than for all ages, in contrast to Italy and Malaysia, but more likely to be killed. This could suggest that their crashes tend to be at higher crash speeds in Australia than in the other regions and could involve more older riders. While crashes among Powered Two Wheelers (PTW) was high in Italy, the proportions of fatal and all injured moped riders outranked that of motorcyclist, highlighting the need for specific focus on these types of vehicles and crashes to ensure these younger adults are better protected in this region.

Pedestrian crashes were proportionately quite high in all three countries but less among young Italy and Malaysian pedestrians, in contrast to Australian statistics. This could suggest that pedestrian crashes are more problematic for older road users in these regions. However, the proportions of pedestrian deaths were higher among the fatally injured in all countries, confirming the increased vulnerability of these road users through lack of protection in a crash. The proportions of bicycle deaths and injured were generally low for both age groups.

4.5 Other Issues

It was argued that injury and deaths due to road traffic crashes is a major public health problem in developing countries\[14\]. More than 85% of all deaths and 90% of disability adjusted life years lost from road traffic injuries occur in developing countries. Among children aged 0-4 and 5-14 years, the number of fatalities per 100 000 population in low income countries was about six times greater than in high income countries in 1998. The highest burden of injuries and fatalities is borne disproportionately by poor people in developing countries, as pedestrians, passengers of buses and minibuses, and cyclists.

5 COUNTERMEASURES

The findings from this analysis raise a number of potential opportunities for countermeasures to address this growing burden of death and injury to Vulnerable Road Users.
**Motorcyclists** – there are a number of potential countermeasures to address motorcycle crashes. ABS technology seems to offer good benefits in preventing the crash from happening, as well as better positioning the motorcycle if a crash in unavoidable[8]. Moreover, training programs to better prepare riders (especially novice ones) seem to have meet with some success[15]. Moped riders in Italy and Malaysia often involve very young riders who would seem to be a particular target group for improved training prior to licensing. Graduated licensing for these road users would be worthy of further consideration.

There are also engineering countermeasures to improve outcome such as roadside barriers, separate motorcycle lanes, and Black-Spot motorcycle road treatments. Rider’s helmets that provide superior head and face protection and protective riding equipment are critical for mitigating injury. Finally, reducing travel speed, which will reduce the likelihood of a crash and/or reduce injury through better energy management, would also be very helpful, although it may prove difficult to get this group to comply.

**Pedestrians** – countermeasures to aide pedestrian safety are less frequent and often involve primary safety. Barriers to prevent pedestrian movements in particularly hazardous locations have been used with relative success, and more distinctive and frequent pedestrian crossings can help stream pedestrians. Traffic signals at pedestrian crossing on busy roads aide the elderly and disabled to cross at busy city roads and intersections.

**All Road Users** – Malaysia has recently acknowledged that to achieve their mission of a road safety level in Malaysia at par with the developed countries by 2010[10], they recognise the need for greater education, awareness and advocacy programmes, improved legislation and policies to reduce injury accidents and fatalities to the minimum level. Adopting a Vision Zero approach is necessary to help achieve their mission. Countries such as Australia and Europe have long adopted such a model in addressing road safety targets with reasonable success. Legislation that establishes traffic law and the related sanctions needs to be framed so as to target the factors that most increase road risk. Sanctions applicable for exceeding urban speed limits need strengthening – the practice that most endangers vulnerable road users.

6 **CONCLUSIONS**

Public policy response to this growing epidemic in developing countries has been muted at national and international levels and policy makers need to recognise this growing problem as a public health crisis and design appropriate policy responses. With growing usage of VRU transport in developing countries, this burden is expected to become even larger in the years ahead in these regions without urgent attention.

**Limitations** - The databases chosen for these analyses are representative samples of police-reported real-world crash data in these countries. While they are the best available databases in these regions for conducting detailed analyses of crash and injury outcomes, they are nevertheless quite varied in terms of the data collected, the criteria applied and the level of comprehensiveness. Thus, these analyses need to be viewed with some caution in the light of potential deficiencies. In particular, the under-reporting of serious and minor injured VRUs is claimed to be as high as 50% to 65% of cases for pedestrians and 80% for cyclists[3].

**Acknowledgements**

We are grateful to Mr. Antonio Bagalà with the cooperation of Mrs. Emanuela Di Pasquale for undertaking and providing the Italian data and for the generous cooperation provided by the Automobile Club of Italy. We also thank the Malaysian Institute of Road Safety Research (MIROS) for their valuable assistance in providing the Malaysian data analysis and to Sharifah Allyana Syed Md Rahim for her efforts in undertaking the data analysis.
REFERENCES


9. European road safety day


ABSTRACT

Pedestrians are typically defined as people travelling on foot although for purposes of transportation planning, the definition can be expanded to include those travelling on roller skates, skateboards, and wheelchairs, and can also include persons pushing prams, delivery carts or other devices. The rewards of creating a safe and available pedestrian infrastructure have been demonstrated by many cities across the globe with benefits to the health and stability of the community and environment as well as the potential positive impact on tourism and the economy.

In 2001, 49 pedestrians were killed on Dubai roadways. Over the following six years, the number of fatalities nearly tripled to 145 in 2007, accounting for 44% of the Dubai roadway fatalities. To address the rising rate of pedestrian crashes, the Traffic Department of the Dubai Roads & Transport Authority (RTA) has developed a Pedestrian Safety and Mobility Action Plan that will guide infrastructure and policy improvements to increase walking safety for Dubai residents and visitors. The three-year goals of the plan are a 30% reduction in pedestrian fatalities and a 20% increase in pedestrian traffic. The long range vision for the plan includes a “Vision Zero” statement indicating that the ultimate goal is to eliminate all pedestrian fatalities from the roadway.

The Action Plan was developed for Traffic & Roads Agency of RTA by Alta Planning + Design, a US-based non-motorized transport planning consultancy. The work was organized into three phases: Phase 1 involved an evaluation of existing pedestrian conditions in Dubai including study and analysis of accident data, road standards, plans, interviews with key stakeholders and the production of a GIS-based Pedestrian Demand Model that identifies pedestrian attractors and detractors to provide an understanding of pedestrian activity and risk exposure. Phase 2 was a compilation of research and standards from 15 international cities to gain an understanding of international best practices around the world for pedestrian safety and to look at some of the countermeasures that might be adapted for use in Dubai to improve pedestrian mobility and safety. Phase 3 comprises the complete Pedestrian Safety and Mobility Action Plan document and focuses on specific recommendations for pedestrian infrastructure improvements as well as legislative and policy directives to ensure that the roadway network is safe and accessible for pedestrians.
1 BACKGROUND

Dubai is a city full of pedestrians. Recent travel surveys have found that 19 percent of trips in Dubai are undertaken by walking (Dubai RTA, 2007). In dense areas such as the Bur Dubai and Deira central business districts, rates of walking are even higher. Even for those who travel predominantly by other modes, walking remains a fundamental way for people to get around. A basic premise of pedestrian planning is that everybody is a pedestrian. Whether undertaking an entire walking journey, a walk from home to the bus stop, or simply a walk from their parking space to their building entrance, a large number of people in Dubai complete at least some of their trips on foot.

Dubai’s rapid economic and population growth has been accompanied by an equally rapid expansion of the roadway network. Projects implemented to maximize vehicular mobility have resulted in a deteriorating pedestrian environment. The overall number of pedestrian crashes as well as the number of crashes per 100,000 population have been rising steadily over the past several years and Dubai now has one of the highest pedestrian crash rates in the world.

There are various reasons to take measures to bring about a safe and convenient pedestrian environment. The global trend of rising automobile use is putting increased pressure on urban roadways as cities are faced with ever increasing traffic congestion. Development patterns that focus exclusively on the movement of automobiles have led not only to serious traffic problems, but also have safety, health and environmental consequences. For residents who do walk – either by choice or because of a lack of other mobility options – moving around on foot becomes a test of nerves as they dash across roads in front of speeding vehicles, encounter obstacles in every footpath and manoeuvre around work zones, with the risk of being involved in a traffic collision always present. Dubai residents should have the basic right to walk without unnecessary inconvenience or fear for their personal safety.

For these and other reasons, many cities have begun major investments toward improving pedestrian safety and mobility. Increased pedestrian travel relieves pressure on the roadway network and can reduce the severity and duration of traffic congestion. Walking is also a critical element of transit trips. While walking only trips are not always feasible when trip distances are long, providing for safe and convenient pedestrian travel is essential to encourage the use of rail, bus and other transit modes. Promoting walking is also a key element to addressing local and global environmental concerns. From health problems related to poor air quality and physical inactivity to global climate change, cities around the world are investing in pedestrian facilities to improve the health of local residents and minimize greenhouse gas emissions.

A vibrant pedestrian environment is a defining feature of many global cities, helping to create spaces for social interaction and civic life. It is widely documented that people prefer to live in walkable communities and that pedestrian amenities contribute to the livability of a city. As Dubai keeps an eye on its future economic growth, the desirability of Dubai as a world-class destination for both work and leisure will depend in part on its ability to effectively reverse the trend of increased pedestrian injuries and fatalities.

2 GOALS OF PEDESTRIAN SAFETY AND MOBILITY ACTION PLAN

As its name implies, the Action Plan is focused on improving both the safety and mobility of pedestrians in Dubai.

- Safety refers to the risk for pedestrians of being involved in a collision with a motor vehicle when they are walking in Dubai.
- Mobility refers to the ability of pedestrians to move around Dubai on foot, to reach their destinations in a direct and convenient manner.
Together, safety and mobility represent the two main considerations for pedestrians who are contemplating a walking trip in Dubai. Improving safety and mobility means a) reducing the number of pedestrian collisions and b) improving pedestrian facilities such that more people choose to walk in Dubai.

The plan supports the RTA’s Strategic Goals and objectives to promote more sustainable forms of transport. Particularly with Dubai’s investment in a world-class Metro and bus system, there is a renewed focus on the need for people on foot to be able to safety and conveniently access these transit systems. The recommendations contained in the plan are intended to make Dubai’s roads safer and more convenient for the thousands of existing pedestrians, and help to encourage new pedestrian activity for commuting, tourism and recreation.

3 PEDESTRIAN CRASH ANALYSIS
A major reason for developing the Action Plan was the increasing rate of motor vehicle crashes involving pedestrians on Dubai’s roadways in recent years. Pedestrian injuries and fatalities represent a major traffic safety problem in Dubai. Figure 1 shows the number of motor vehicle crashes involving a pedestrian for the five years between 2004 and 2008. All data is based on RTA crash records (Dubai RTA, 2009). As can be seen, there has been an upward trend over the study years.

The number of pedestrian crashes is increasing at a rate faster than Dubai’s population, which has risen from 1.2 million in 2004 to more than 1.6 million in 2008. Figure 2 indicates that the crash rate per 100,000 population increased over the same time period. The crash rate was approximately 40 per 100,000 between 2004 and 2006, increased to 46 in 2007 and jumped to 49 in 2008.

Figure 1: Dubai Total Pedestrian Crashes, 2004-2008

Figure 2: Dubai Pedestrian Crashes Per 100,000 Population, 2004-2008
According to RTA’s crash database, there were a total of 3,185 crashes involving pedestrians between the years 2004 and 2008. The severity of injuries sustained by pedestrians in each crash is presented in Table 1 below. The following figure provides this same information on an annual basis. Again, the upward trend in pedestrian crashes is evident. Interestingly, the number of crashes resulting in a pedestrian fatality decreased from 2007 to 2008. However, the number of crashes for all other pedestrian crash severities increased.

Table 1: Severity of Pedestrian Crashes in Dubai, 2004-2008

<table>
<thead>
<tr>
<th>Severity of Pedestrian Injuries</th>
<th>Number of Crashes</th>
<th>Percent of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatality</td>
<td>551</td>
<td>17%</td>
</tr>
<tr>
<td>Serious Injuries</td>
<td>324</td>
<td>10%</td>
</tr>
<tr>
<td>Medium Injuries</td>
<td>1173</td>
<td>37%</td>
</tr>
<tr>
<td>Slight Injuries</td>
<td>1137</td>
<td>36%</td>
</tr>
<tr>
<td>Total</td>
<td>3185</td>
<td>100%</td>
</tr>
</tbody>
</table>

Between the years 1997 and 2001, the number of annual pedestrian fatalities ranged between 45 and 49. The year 2002 saw the start of an upward trend in pedestrian fatalities. By 2007, the number of pedestrian fatalities had risen to 145, more than triple the 48 pedestrian fatalities in 2000. As can be seen in Figure 3, the upward trend was broken in 2008, when the number of pedestrian fatalities decreased significantly to 116. However between 2007 and 2008, the number of crashes involving pedestrians actually increased from 708 to 802 (13%).

In 2000, pedestrians made up 29% of all traffic fatalities. By 2007, the share of pedestrian fatalities had risen to 44% of all fatalities before falling to 39% in 2008. Time will tell whether the decrease in pedestrian fatalities overall and as a percentage of all traffic fatalities in 2008 is the start of a positive new trend or a one year aberration. At the time of this paper complete data for 2009 was not yet available.

Figure 3: Dubai Pedestrian Fatalities, 2000 through 2008

Figure 4 illustrates that pedestrian fatalities per 100,000 population increased steadily from 2001 to 2007. Pedestrian fatalities per 100,000 increased from 5.0 in 2001 to 9.5 in 2007. In 2008, there was a large improvement and the rate dropped to 7.1. By comparison, the
Netherlands and Sweden are the safest countries in the world, with 0.5 and 0.6 pedestrian fatalities per 100,000, respectively. In 2007, the traffic fatality rate was about 4 or 5 times as high as in the safest countries of the world. The pedestrian fatality rate in the same year, however, was 17 to 18 times as high as in Sweden or the Netherlands (WHO, 2007).

Figure 4: Dubai Pedestrian Fatalities Per 100,000 Population, 2000 through 2008

4 PEDESTRIAN DEMAND MODEL

A Pedestrian Demand Model was developed to determine the most likely areas within Dubai for pedestrian activity (existing and future), which areas pose the highest risk exposure to pedestrians, and then combining those two elements to identify which areas have the greatest need for pedestrian improvement and should be the focus of recommendations under the Action Plan. The end result of the model was a map that allowed the project team to identify high priority locations, both citywide and within community areas, that are in greatest need of pedestrian improvement based on pedestrian activity and risk exposure. The model was developed utilizing extensive data sets provided to Alta Planning + Design by the RTA and Dubai Municipality, supplemented with field observation and survey work conducted by the consultant team.

The Pedestrian Demand Model has two basic components: Pedestrian Attractors and Pedestrian Detractors. Pedestrian Attractors identified included transit stations, major employment areas, shopping areas, mosques, schools, government buildings, recreational areas, and key elements of the pedestrian network such as footbridges and subways. Pedestrian detractors identified included high traffic / high speed roadways and known collision areas. Each attractor and detractor was assigned a score and weighting based on its importance as a factor in pedestrian demand.

The model was developed in ArcView GIS, using a Spatial Analyst extension. Using the GIS database, Dubai is divided up into a grid of cells, with each cell representing an area on the ground of 25 x 25 meters in size (625 square meters). This cell size was chosen to capture the best detail possible in relation to the overall scale of the datasets and the geographic size of Dubai. Choosing too small a cell size would create a map that was crowded with too much information; too large a cell size would not provide sufficient detail to pinpoint specific intersection and corridor locations for improvement.

Once the scoring values were assigned to each criterion, the model identifies the characteristics of each particular area in geographic space and assigns a numeric value for each of these characteristics. The score per area is then added to create a ranking for that particular area in geographic space. Figure 5 shows the final pedestrian demand model output map for Dubai. Roadway segments indicated in red and orange indicate the highest priorities.
for pedestrian improvements, as they score high for both existing / potential pedestrian use and major barriers that detract from pedestrian safety.

Figure 5: Dubai Pedestrian Demand Model Output Map

5 KEY RECOMMENDATIONS

The Action Plan contained two general types of recommendations: 1) general recommendations that apply on a citywide level to numerous locations in Dubai; and 2) specific design concepts for the top 100 locations identified from the Pedestrian Demand Model and field surveys conducted by the consultant team. Key citywide recommendations included design enhancements for footpaths, pedestrian crossings, and intersections, as well as improved enforcement of give way behaviour and motorist speeding.

5.1 Footpaths

Footpaths are the most basic element of a pedestrian network. Also referred to as ‘sidewalks’ or ‘pavements,’ footpaths provide for a dedicated pedestrian space within the roadway right-of-way, but separated from the carriageway by an upstand kerb. Within Dubai a basic footpath network is well-established in many of the urbanized areas, but width, pavement conditions and continuity vary widely. Improving the accessibility and comfort of footpaths in Dubai is critical for improving pedestrian safety and mobility.

Several key problems exist related to footpaths in Dubai which directly affect pedestrian circulation and safety:

- **Continuity**: The footpath network is not continuous, even in many the built-out urban areas. Footpaths may only be present on one side of the street, or may stop with no notice. Lack of a continuous footpath causes pedestrians to either walk in the carriageway, or cross the street at a mid-block location to access another segment of footpath to continue their journey.
- **Width**: Many footpaths in Dubai are too narrow to accommodate existing pedestrian flows or people with special needs such as those in wheelchairs.
Footpaths in low-traffic areas should provide a minimum amount of clear space to allow two pedestrians to walk side-by-side comfortably. In higher traffic areas such as major retail frontage, areas with footpath seating, and wherever high levels of pedestrian activity are expected, the minimum widths should be increased to accommodate the expected volumes.

- Obstruction: Even where footpaths are sufficiently wide, the effective pedestrian space is often compromised by the placement of utility poles, parking meters, signs, or street furniture in the middle of the pedestrian ‘Through Zone’ (see description below). Blocked footpaths force pedestrians to step off the kerb into the carriageway to move around an obstacle. In some instances, the incorrect placement of these items is necessitated by the location of underground utility lines - utilities are placed under tiled parking spaces or footpaths so they can be easily accessed by removing tiles rather than excavating the road surface. This section discusses general recommendations aimed at improving the functionality of footpaths for pedestrians.

- Lack of Dropped Kerbs at Intersections: Dropped kerbs are lacking at many intersections in Dubai. A lack of dropped kerbs at intersections creates difficulties for pedestrians with disabilities, children, and those pushing baby carriages, carts or luggage. Properly designed dropped kerbs provide a smooth transition from the footpath to the roadway and provide a visual cue for the proper location for pedestrians to step from the footpath into the roadway.

- Driveways: Driveways frequently constitute an interruption in the pedestrian environment in Dubai, creating potentially hazardous situations for pedestrians. The presence of upstand kerbs or steeply graded dropped kerbs creates difficulties for pedestrians with disabilities, children, and those pushing baby carriages, carts or luggage. Properly designed driveways should rise to meet the footpath, reinforcing the idea that motorists should use caution and slow speeds when crossing the pedestrian zone.

The Action Plan provides recommendations to ensure that all footpaths in Dubai maintain minimum widths for the Pedestrian Through Zone (the area dedicated for pedestrian travel). In order for two people to walk comfortably side-by-side a 1.8 meter minimum Through Zone is recommended. Areas with higher pedestrian volumes, such as commercial, retail or restaurant districts, warrant a wider Through Zone. The expected volume of pedestrians should always be studied in order to properly size the width of the Through Zone. Table 2 shows recommended minimum preferred and minimum widths for footpaths on various roadway classifications in Dubai.

Table 2: Recommended Minimum Zone Widths by Roadway Type (m)

<table>
<thead>
<tr>
<th>Roadway Type</th>
<th>Furnishing Zone</th>
<th>Through Passage Zone</th>
<th>Frontage Zone</th>
<th>Total Footpath Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Arterial, Pedestrian District</td>
<td>1.2</td>
<td>2.5</td>
<td>0.3 – 0.6</td>
<td>4.3 or more</td>
</tr>
<tr>
<td>Secondary Arterial</td>
<td>1.2</td>
<td>1.8</td>
<td>0.2 - 0.35</td>
<td>3.35 or more</td>
</tr>
<tr>
<td>Local/Collector Street</td>
<td>1.2</td>
<td>1.8</td>
<td>0 - 0.25</td>
<td>3.15 or more</td>
</tr>
</tbody>
</table>

Maintenance of the minimum pedestrian Through Zone means that objects such as street signs, parking pay kiosks, lighting standards, benches, landscaping, advertising panels,
and other street furnishings must not be installed in the centre of the footpath where they block pedestrian travel. Adherence to these guidelines requires coordination among all of the various departments within Dubai RTA that are responsible for installing signage and other furnishings in the street environment.

5.2 Crossing Enhancements
Crossings are the most important element of pedestrian safety, since these are the locations where the pedestrian environment and the motor vehicle environment directly interact. The design of safe crossings on all types of roadways in Dubai must be accommodated, whether that means a slow-speed neighbourhood street where a resident can safely walk across the road at any point, or a pedestrian footbridge across a high-speed freeway that completely separates the pedestrian and motor-vehicle users.

Freeways and expressways account for almost 34% of all pedestrian fatalities in Dubai. The solution for reducing the number of pedestrian fatalities that occur on freeways/expressways is perhaps the most straightforward, as the only possible option to increase pedestrian crossing safety is complete grade separation in the form of a footbridge or subway.

The other 66% of pedestrian fatalities in Dubai occur on arterial roads and collector and local roads. Addressing pedestrian fatalities on these roads is a greater challenge, as the amount of pedestrian activity is much higher and more dispersed, and it is simply not possible to grade separate every crossing location. A general lack of safe crossings facilities at junctions, bus stops, along long arterial segments, and at other locations where a zebra crossing is not provided adjacent to a major generator causes pedestrians to cross roads at unmarked locations (“jaywalking”) and exposes them to danger when suddenly faced with high-speed approaching vehicles.

Recommendations to improve pedestrian safety at crossings include installation of enhanced crossing signage, improvements to right turn slip lanes, and reductions in the corner radii at intersections.

5.2.1 Crossing Signage
Appropriate and visible signage can play an important role in increasing the visibility of pedestrians at a crossing and can also help encourage drivers to slow down and give way. The current give way to pedestrians sign consists of a normal give way sign with a small rectangular pedestrian sign posted below it. This sign is installed wherever there is an unsignalized crossing. Based on interviews with pedestrians, driving instructors, and field observation it is evident that the existing sign may not be visible or clear enough to encourage vehicles to give way to pedestrians as they are required to do so by UAE law. Therefore, it is recommended that RTA adopt the blue and white sign depicted in Figure 6 that is currently in use in many countries around the world. The blue colour is much more visible and may help with give way compliance in Dubai.

Figure 6: Recommended Pedestrian Warning Signage for Unsignalized Crossings
5.2.2 Slip Lane Treatments
Slip lanes can be a major challenge for pedestrians at otherwise well-designed signalized intersections. Drivers passing through a slip lane are usually focused on maintaining speed through the curve and merging into traffic and are not always aware of pedestrian crossing activity. Slip lanes designed with large corner radii enable vehicles to travel at high speeds as they pass through the pedestrian crossing. Some newer signalized junctions have extremely large, sweeping slip lanes that facilitate corner speeds of 60-80 km/h.

There are several design treatments that can improve pedestrian safety by reducing vehicle speeds and/or improving pedestrian visibility at slip lanes, shown in Figure 7. Designing smaller corner radii forces vehicles to slow down as they negotiate the slip lane. Blue pedestrian crossing signs (discussed above), which are more visible than the current pedestrian crossing sign, should be placed on both sides of the crossing to alert motorists to pedestrian activity. An alternate ‘sharks teeth’ give way marking, recommended as a more visible alternative to Dubai’s standard dashed line give way marking, is recommended in advance of the crosswalk.

Raised crossings force the driver of the vehicle in the slip lane to pay greater attention to the pedestrian crossing. Raised crossings can be added at slip lanes with moderate amounts of pedestrian traffic, or in locations where it is desired to use the raised crossing as a traffic calming device to reduce vehicle speed through the slip lane. It is not uncommon to encounter a speed hump right at the exit to a slip lane in Dubai, this configuration allows higher speeds through the pedestrian crossing and forces the vehicle to slow down only when merging into through traffic.

At certain junctions in Dubai, it is advantageous to provide a protected pedestrian crossing by signalizing the slip lane in coordination with the regular traffic signal. This is the case at many of the arterial junctions in the central business district areas or where pedestrian volumes are high. Additionally, signalizing slip lanes makes sense at two-lane slip lanes where a pedestrian is not guaranteed a safe crossing if one lane of travel gives way and the other does not.

![Figure 7: Recommended Enhancements at Slip Lane Pedestrian Crossings](image)

5.2.3 Corner Radius Reductions
Providing the large corner radii and the splitter island at the mouth of the junction necessitates locating zebra crossings back from the intersection on the cross street. This forces pedestrians to divert from their desired line of travel to reach the zebra crossing. Most pedestrians observed in Dubai are not making this detour and are crossing in line with the footpath along their ‘desire line’. In addition, these large corner radii allow for high cornering speeds by vehicles, which cause safety issues for pedestrians the intersection.
As shown in Figure 8 below, the larger the corner radii the farther the pedestrian has to walk out to reach the zebra crossing. Providing for smaller corner radii improves allows pedestrians to cross along the footpath desire line, shortens the crossing distance, and increases pedestrian visibility to motorists approaching the crossing. A smaller corner radii also lowers vehicle entry speeds into neighbourhoods, and signals to motorists that they are entering residential areas and need to slow down. Lower corner radii are only a minor inconvenience to heavy vehicles, as they simply have to adjust their entry angle into the corner. The largest vehicles in Dubai only make up a fraction of the traffic on these lower order streets and may have to adjust their driving patterns slightly. The safety of all users should not be sacrificed for a fraction of the roadway traffic that may be inconvenienced.

Figure 8: Pedestrian Desire Line Compared with Various Corner Radii

5.3 Footbridges and Subways
Footbridges and subways, or grade-separated crossings, provide pedestrians with the highest degree of separation and protection from vehicular traffic. However, if grade separation involves the pedestrian changing level by stairs or ramp and it is not convenient to use, alternative and potentially hazardous routes are often chosen. This can be overcome only by creating physical barriers at grade level to force the pedestrian to use the grade separated facility. The Action Plan recommends the continued use of fence barriers across roadway medians where footbridges and subways exist, in order to discourage jaywalking and encourage the use of the grade-separated facility.

5.4 Give Way Behaviour
Article 5 of the UAE Federal Traffic Law No. 21 of 1995 Regarding Traffic states that drivers must stop to allow pedestrians to cross the road at marked pedestrian crossings. This establishes that pedestrians have a right to cross the road in a zebra crossing and expect that motorists will give way to them once they have started crossing. Based on field observations and surveys, this provision of the Federal Traffic Law appears to be widely unknown or misunderstood by both motorists and pedestrians, and is rarely enforced by Dubai Police.

Motorist compliance with this law is very low in Dubai. Field observations of roadway user behaviour completed at several crossings during this project indicate that motorists rarely adapt their speed or give way to pedestrians at uncontrolled crossings. Pedestrians at zebra crossings wait for an average of almost 20 cars to pass before being able to cross arterials and local roads. Drivers tend to maintain high speeds while passing uncontrolled zebra crossings, effectively delegating responsibility for a safe crossing to the pedestrian.

It is important to both increase the police enforcement of the Federal Traffic Law and increase the number of controlled pedestrian crossings. Pedestrian-activated ‘Pelican’ crossings are present at some locations throughout Dubai. Another innovative crossing signal
know as a ‘Puffin’ utilizes automatic pedestrian detection to cancel unwanted pedestrian phases and extends crossing times for slower pedestrians.

Infrastructure/technology can also be used improve give way behaviour. A device recently developed in Sweden, known as Automatically Warning & Detection at Pedestrian Crossings (AWDP), has shown good results with respect to vehicular speeds and give way behaviour at pedestrian crossings. Automatic pedestrian detection triggers LED signs that flash ‘Yield to Pedestrians’ or a similar message/symbol for 10-20 seconds. LED signs are placed 20 meters in advance of the pedestrian crossing or over the crossing itself. Two signal posts placed at the crossing detect pedestrians wishing to cross and trigger the warning message as shown in Figure 9. Alternatively, the message sign could be triggered with a pedestrian push button.

![Figure 9: Automatic Warning and Detection of Pedestrian at Crossing Design](image)

5.5 Speed Management
Research indicates that even small increases in speeds can result in rapid increases in the risk for serious crashes causing death or injury. Recognizing the strong relationship between vehicle speeds and the frequency and severity of crashes, cities such as Sydney and Singapore have instituted a 50 kph speed limit within the city limits. To reduce the frequency and severity of pedestrian crashes, RTA should consider adopting lower speed limits in certain areas of Dubai. Because reduced speed limits require enforcement to be effective, this measure should be used in conjunction with increased deployment of visible stationary police enforcement and speed cameras.

6 CONCLUSIONS
Implementation of the recommendations of the Dubai Pedestrian Safety and Mobility Action Plan will have a significant effect toward enhancing the pedestrian environment in the Dubai Emirate. It is anticipated that with these enhancements to footpaths, crossings, speed management, and other pedestrian-related infrastructure, the trend of a continued reduction in pedestrian fatalities seen in 2008 will continue. These pedestrian improvements will not only improve safety, but will contribute to the overall quality of life in Dubai, and help to support Dubai’s investment in Metro and bus transit. This Action Plan is the first step toward the RTA’s “Vision Zero,” a long-term goal that no pedestrians will be killed or seriously injured in traffic accidents.

REFERENCES
Dubai Roads & Transport Authority (2009), Pedestrian Crash Data for Years 2002-2008
COMPARATIVE CROSS-CULTURAL ANALYSES ON ROAD SAFETY AMONG VULNERABLE ROAD USERS

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ABSTRACT
Globally, the WHO (2009) estimates that approximately 1.2 million people die annually from road traffic crashes especially among vulnerable road users (i.e. children, pedestrians, cyclists and the elderly). Human-related factors such as culture, risk perception, attitudes and risk-taking behaviour contribute substantially to this safety problem. Surveys on risk and safety are, however, rare especially in Sub-Saharan Africa. Thus, this present study aims to analyse some cultural aspects of risk with respect to road safety by comparing a sample population in Ghana and Norway respectively. Judgment of traffic injury risks, attitudes and behaviours towards road safety, and the role of culture between road users are also explored. An additional objective is a discussion of the suitability of application of various road safety strategies for developing countries. The choice of these two countries are informed by the fact that they differ largely on levels of infrastructure development to minimise exposure of vulnerable road users to traffic injuries; degree of motorisation and consequent high incidence of traffic accidents as well as their cultural values.

The analyses are carried out from a similar questionnaire survey data used by generated through stratified sampling of respondents (N = 299) in the Ghanaian cities of Accra and Cape Coast, as well as a representative sample of the Norwegian public above 16 years (N = 247). Stratified analyses of mean (sum) scores for risk perception, attitudes and behaviour and in addition regression models were performed for explaining variance for the two countries.

The results show that Ghanaian vulnerable road users report higher injury risk perceptions than their Norwegian counterparts. Ghanaians also express more favourable safety attitudes and safety behaviour, except for drinking and driving. These finding may be interpreted in relation to the differences in the traffic system and the overall risk environment in the two countries. Age, gender and education are generally insignificant predictors for attitudes and behaviour both in Ghana and Norway, except partly for gender in the latter. Certain cultural traits, such as sounds, honking of horns and other movements in traffic are more important than the influence of traffic signs on attitudes in Ghana. However, most elements of culture are embedded in the systematic country differences.

More holistic strategies at the micro, meso and macro levels seem to be most appropriate for reducing risk culture, risk attitudes and contribute to safety-mindedness in behaviour. These include: individual and collective behavioural improvements through well-publicised and sustained road safety education emphasising personal responsibility in traffic, strict enforcement of legislations on the use of seatbelts, child restraints, and crash helmets as well as random breath-tests to check drink driving and the construction of speed calming facilities in risk-prone areas will positively affect safety behaviour and improve road safety.
1. INTRODUCTION

Road deaths will rank the fifth leading cause of death by 2030, leading to a projected 2.4 million fatalities annually (WHO, 2008). Translated into percentage terms, over 90% of the global deaths are said to occur in low and middle-income countries of the world, which have just 48% of the global vehicle population. Almost half of these road fatalities involve ‘vulnerable road users’, a collective term for pedestrians, cyclists or users of motorized two-wheelers and in addition, passengers in public transport. With an estimated global losses of US $ 518 billion due to road traffic injuries, low and middle-income countries spend between 1% and 3% of their gross national product—more than the total amount they receive in development assistance (Jacobs et al, 2000; Peden et al, 2004) to cover morbidity, mortality and other property-related costs (Odero et al, 1997).

It is argued that risk-taking behaviour in traffic is the most important variable for involvement in traffic accidents (Jonah, 1986). Thus, if risk perception affects behaviour, then it would be possible to change behavioural patterns through influence of risk perception (Rundmo, 1999). For instance, perceptions of risk and risk-taking attitudes of motorists contribute to road fatalities through crashes with vulnerable road users. Other factors, such as risk-taking attitudes of vulnerable road users themselves, the intensity of traffic mix and the lack of separation of vulnerable road user groups from fast-moving motorised vehicles, have heighten the risk of injury and fatalities for these less-protected road users (Ameratunga et al, 2006).

In view of the fact that current studies on risk perception are mostly conducted in high income countries, broader surveys on risk and safety are rare in Sub-Saharan Africa. This present study, therefore, analyses cultural differences with respect to road safety issues in a high income country (i.e. Norway) and a low income country (i.e. Ghana). By reason of the huge differences in terms of socio-economic development, these two countries could best typify the overall human factor characteristics of road traffic safety in both the high and low income countries respectively.

In Norway, for instance, even though the year 2007 recorded a crude death rate of 5.2 per 100,000 people (233 fatalities), comprising 70% males, most of whom were occupants of vehicles, the country has adopted what it calls the ‘zero vision policy’ which states, inter alia, that road fatalities are unacceptable and that both authorities and individuals in traffic share the mutual responsibility for traffic safety (The Norwegian Directorate of Public Roads, 2006; Lund & Rundmo, 2009). A lot of intervention measures have been put in place to attain this noble vision. These include, but not limited to, strict enforcement of drink-driving laws; seat-belt and helmet wearing laws; child restraint laws and promotion of alternative forms of transport like walking or cycling (WHO, 2009).

Ghana, like many low income countries, on the other hand, records an unacceptably high road traffic fatalities, with a crude death rate of 8.6 per 100,000 people (2043 fatalities) in 2007, for instance. The majority of these fatalities (c. 42%) involve pedestrians in the 26-35 year group who inhabit the urban areas of the country (London et al, 2002; Afukaar et al, 2003; Republic of Ghana, 2007). This sad phenomenon prevails notwithstanding the several intervention measures put in place by stakeholders to engender cultural and behavioural changes with regards to traffic safety and peoples’ judgement of traffic risks. These measures have focused primarily on road safety education and training programmes to school children, teachers, parents and commercial vehicle drivers in both the print and electronic media. However, laws on drink-driving, use of seat-belts, crash helmets, child restraints etc are seldom enforced in Ghana. Again, there are no national policies to promote alternative transport and well-developed traffic separation system, albeit scant traffic calming schemes for residential areas and the city centre are identified.
Against this backdrop, the specific aim of this present study is to explore peoples’ judgement of traffic risks, attitudes and behaviours towards traffic safety, and the role of culture on road safety among some vulnerable road users in the two countries. In addition, the suitability of application of various road safety strategies for Ghana and other developing countries is discussed.

3. METHODS

3.1. Sample and Data Collection Procedure

This present study made use of questionnaire surveys for respondents who are above 16 years old. Data was generated in 2006 through stratified sampling of respondents (N = 299) in the Ghanaian cities of Accra (c. 2 million inhabitants) and Cape Coast (c.82,000 inhabitants), as well as a representative sample of the Norwegian public (N = 247). In Ghana, the response rate was 85 %, based partly on interviewer administrated method and partly through postal surveys. On the basis of gender, a total number of 145 female respondents (representing 50 %) and 143 male respondents (also representing 50 %) took part in the Ghanaian survey. Categorising respondents according to their ages, the 26-49 year group represents the majority of the sample population (N= 150). This involves 56 % males and 44 % females. In this sample population, the elderly constitutes a small fraction, especially when gender is taken into consideration.

A response rate of 23 % was achieved for Norway. In contrasts with Ghana, a substantially higher proportion of the elderly (i.e.50-90 years), comprising 60 % male and 40 % female respondents took part in the Norwegian survey. Table 1 further illustrates the gender and age group sample distribution by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Age groups</th>
<th>Gender</th>
<th>Total (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>females</td>
<td>males</td>
</tr>
<tr>
<td>Ghana</td>
<td>17-25 years</td>
<td>61.8 %</td>
<td>38.2 %</td>
</tr>
<tr>
<td></td>
<td>26-49 years</td>
<td>44.0 %</td>
<td>56.0 %</td>
</tr>
<tr>
<td></td>
<td>50-90 years</td>
<td>21.1 %</td>
<td>78.9 %</td>
</tr>
<tr>
<td>Norway</td>
<td>17-25 years</td>
<td>72.0 %</td>
<td>28.0 %</td>
</tr>
<tr>
<td></td>
<td>26-49 years</td>
<td>67.5 %</td>
<td>32.5 %</td>
</tr>
<tr>
<td></td>
<td>50-90 years</td>
<td>40.0 %</td>
<td>60.0 %</td>
</tr>
</tbody>
</table>

Clearly females were overrepresented for both countries in the youngest age group and for the 26-49 years group in Ghana. This skewed distribution is well known from several surveys. Young females are more devoted to fill in forms than young males. Weighting or stratified analyses to correct for these gender-age imbalances were, however, not performed. The majority of the analyses and especially, all of the multivariate analyses are controlled for gender, in such a way that gender-skewed distributions influence the results and the conclusions drawn to a minimal degree.

The data collection in Ghana was done primarily by supervisors and master students from the Norwegian University of Science and Technology (NTNU) as well as representatives and master students from the University of Ghana and the University of Cape Coast. The researchers accosted respondents from different suburbs of the two Ghanaian cities in order to obtain cross-sectional views that could best represent the Ghanaian society.
Even though the questions were all written in the Queen’s language, the Ghanaian researchers interpreted the questions into the local dialects to the understanding of respondents who could neither speak nor write in English language and their responses were recorded accordingly. However, since the majority of the respondents could speak in the medium of instruction, they filled the questionnaires themselves with the assistance, where necessary, of the researchers. While self-reports can be a very convenient means for studying motives, attitudes and risky driving behaviour, anonymous surveys may provide reliable in-depth information. Therefore, with regards to data generation in Norway, the questionnaire was administered through postal survey only.

3.2. Questionnaire and Statistical Analyses

The questionnaire covers a set of items on attitude, culture, risk perception, behaviour plus the most common background variables of respondents. The various scales and items used in the questionnaire are mentioned in relation to the relevant sections of analysis below. Analyses of means for data stratified by gender, age and education are performed for risk perception, attitudes and behaviour. Again, factor analyses are carried out to generate dimensions for culture, attitudes, and behaviour since single items could be unstable and less reliable. In these analyses, we use the Ghanaian material to establish dimensions. Linear and logistic regressions are further applied to uncover influential factors for the attitude and the behaviour dimensions respectively.

Based on previous studies, some differences in terms of risk perception, risk sensitivity and risk willingness in traffic due to cultural differences are found (Lund & Rundmo, 2009). In this present study, even though we made use of the same data material for complementarily studies, we have taken a step further to perform several pre-analyses (for instance, factor analyses) to emphasise the differences in cultural and attitudinal item scores between the two countries. As a point of departure, we focused on the results and patterns from Ghana (e.g. in creating dimensions from factor analyses) while using the corresponding Norwegian results as a reference material.

Furthermore, we adopted a multivariate approach by carrying out a factor analysis to identify factors (dimensions) from single items that gave a more robust measure on attitudes and behaviour. Loaded variables were checked for adequate reliability (measured by Cronbach’s alfa). Beyond this, model selection for multivariate analyses were conducted based on searching for potential regressors in a multivariate linear regression approach. Several regressions where run including check for normal distribution for each value of the independent variable, diagnoses for collinearity, heteroscedasticity and model fit. The ‘enter’ method for entering (non-transformed) independent variables was applied, in preference to ‘forward’ or the other options. Finally, we run a logistic regression in the case where the outcome variable had a suitable distribution for transformation into a binary variable, such as a very restricted range of self-reported values for attitudes towards drinking and driving.

3.3. Data Limitations and Biases

First, in spite of earlier findings that have shown that cultural traits play a substantial role in road safety among the two countries, it may be hard to operationalise and measure in a quantitative approach, those observed traits. Differences in risk perceptions, risk attitudes and behaviour are rooted in a cultural and socioeconomic context. The welfare level, type of organisation of societies, social coherence and respect, as well as the degree of mutual trust and understanding within the population are all embedded in cultural bearings, which also influence the risk culture and the pattern of driving. Culture may have many expressions, both regarding ‘general’ culture which comprises elements of symbols, signs, values, norms and practices as well as traffic related culture.
Second, while the questionnaire was carefully structured to elicit data on culture, attitude and behaviour items, the fact that it was developed in a high-income country could lead to misunderstandings, misinterpretations or even give rise to expected answers and ‘pretence’ filling-in patterns. However, since the questionnaire was pretested and adjusted with inputs from the Ghanaian research group, this bias could not have significantly affected the quality of our data.

Third, since a high proportion of the Ghanaian data was generated through interviewer-administered questionnaires, in contrast with the exclusive postal surveys for the Norwegian respondents, there are reasons to expect that scopes for “noise”, biased answers and misunderstandings could be higher in the former than the latter.

Fourth, the data could be limited due to differences in the survey populations. In Ghana, for instance, the survey was undertaken solely in the urban areas, in contrast with the Norwegian survey which is not urban biased. In cities, people are much more sensitive to risk to the extent that respondents could actually overestimate risk and risk awareness. Coupled with this, there is an oversampling of the well-educated in Ghana, especially of university students, which may obscure the true or traditional Ghanaian traffic-related cultural traits as these respondents are more inclined to be ‘global’ in their risk attitude and behavioural pattern by reason of their association with Western culture. Among Norwegians, on the other hand, risk-taking behaviours do not necessarily drop with higher education, the only exception being peoples’ attitudes on drinking and driving. Finally, 20 respondents in Ghana and 2 respondents in Norway have missing code for the age item. These considerations call for further attention and research on differences among countries.

3. RESULTS

3.1. Risk judgement regarding some vulnerable groups in Ghana and Norway

Risk judgement or perception of risk is a subjective socio-cultural phenomenon. According to Weinstein (1980) and Lund & Rundmo (2009, p. 548), risk judgement is a true reflection of ‘the values, symbols, history and ideology of people living in different cultures’. Owing to differences in socio-cultural practises and lifestyles across space and time, individuals in societies understandably judge or perceive risk differently. A multitude of factors could account for the observed differences in risk judgement among people. A review of current studies by Lund & Rundmo (2009) for instance have revealed some of these factors to include: varying degrees of familiarity with, and perceived control over risk (Gleitman, 1995); gender and age (Trankle et al, 1990; Parker et al, 1992; Slovic, 1992; Spolander, 1993; Sjøberg et al, 1996; Deery, 1999); size of population (Goszczynska et al, 1991); standards of living (Nyland, 1993; Sjøberg et al, 1996); as well as religious practises and occupation (Kouabenean, 1998).

In consonance with the above, previous studies that have been conducted in both Ghana and Norway have concluded that assessment of the ‘risk culture’ between the two countries are significantly different from one another (Jørgensen & Abane 1999; Mock et al, 1999; Afukaar et al, 2003; Lund & Rundmo, 2009). The differences are rooted in varying socio-economic development, living conditions, cultural practises and physical conditions such as the built up environment and to some extent climate.

As illustrated in Table 2 below, both males and females in the Ghanaian sample population judge injury risk comparatively higher than the Norwegian sample, except for Norwegian female drivers and bikers. This finding confirms early studies which state that due to its comparatively dense population, inadequate infrastructure and extreme poverty with its associated consequence of struggle for survival, Ghanaians are exposed to a more hazardous and stressful traffic environment than their Norwegian counterparts (ibid).
However, differences between the countries’ population regarding judgement of consequences of stated possible accidents were not significant.

Table 2: Mean score on four single items ‘How probable is it that you would be injured’ by gender. 5-points scale where 1= very high probability, 5= no probability.

<table>
<thead>
<tr>
<th>Item</th>
<th>Gender</th>
<th>Country</th>
<th>Mean</th>
<th>SD</th>
<th>P value for difference</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision with a pedestrian</td>
<td>females</td>
<td>Ghana</td>
<td>2.76</td>
<td>1.42</td>
<td>&lt;.01</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Norway</td>
<td>3.29</td>
<td>1.26</td>
<td></td>
<td>144</td>
</tr>
<tr>
<td>As a driver of a motor</td>
<td>females</td>
<td>Ghana</td>
<td>2.33</td>
<td>1.44</td>
<td>n. s (.09)</td>
<td>141</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Norway</td>
<td>2.58</td>
<td>1.06</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>As a rider of a bicycle</td>
<td>females</td>
<td>Ghana</td>
<td>2.29</td>
<td>1.40</td>
<td>n. s (.12)</td>
<td>139</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Norway</td>
<td>2.53</td>
<td>1.23</td>
<td></td>
<td>141</td>
</tr>
<tr>
<td>As a pedestrian</td>
<td>females</td>
<td>Ghana</td>
<td>2.27</td>
<td>1.41</td>
<td>0.03</td>
<td>139</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Norway</td>
<td>2.62</td>
<td>1.28</td>
<td></td>
<td>143</td>
</tr>
</tbody>
</table>

Split by age groups, this study reveals that the youngest age group (i.e. 17-25 years) clearly show highly significant differences in mean score on risk perception between the two countries, except for ‘collision with a pedestrian’ (p = 0.06). For the 26-49 year group, there were highly significant differences for all the items. For the 50-90 age group, however, only the item ‘collision with a pedestrian’ showed significant differences between the two countries (p <0.01). These findings also corroborate on previous studies which concluded that adolescents and males show a tendency to be less sensitive to risks and to underestimate the probability and severity of risks caused by traffic situations compared to elderly people and females (Lund & Rundmo, 2009).

When respondents’ level of educational attainment is taken into consideration, this present study reveals that education level has different importance for social status, knowledge and judgements of risks in the two countries. Whereas 6.1% of the Norwegian sample population have obtained the lowest level of education (i.e. primary/secondary school), the proportion in the Ghanaian sample population is 27.8%. However, 40.9% of the Norway sample and 52.1% of the Ghana sample population have college/university education, the highest attainable level. This is not to say that this is the true reflection of the overall education level in both countries. However, this is attributable to oversampling of the highly educated, especially in the Ghanaian survey. For the lowest educational level, there were no significant probability judgement differences between the two populations. For medium level of educational attainment (i.e. high school), differences occurred for all four items, with highest risk judgement for the item ‘as a pedestrian’ among Ghanaians (mean 2.02 versus 2.76).

For the highest education group (i.e. college/university), all the mean differences are significantly different (p = 0.01), with ‘collision with a pedestrian’ showing slightly bigger difference than the others (mean: 2.65 & 3.29 for Ghana and Norway respectively). There exist pronounced differences in probability judgement between the highly educated
populations in the two countries. These findings partly reflect the ‘objective’ road safety level and risk environment in the two countries. In comparison to respondents who had obtained low or basic level of education, it is noteworthy that the Ghanaian respondents with higher education judge injury probability very high for these items. Therefore, one could conclude that an individual’s level of education has a direct bearing on how that individual perceive risks and injury in Ghana. However, beyond the perception, it is not clear whether vulnerable road users with higher education will not indulge in risk-taking behaviour as a driver, a biker, a pedestrian or any other type of vulnerable road users. Here the general stress in everyday life situations reinforced by being encompassed by a risky physical, economical and physical environment play an important role and may nullify a favourable perception.

3.2. Attitudes towards responsibility and safety

A factor analysis was performed for 19 items concerning attitudes with varimax rotation (the most common rotation method) for Ghana. We intentionally selected Ghana as the set study since an inclusion of both countries would have diluted the structure of the attitude dimensions on the questionnaire. The analysis resulted in a first dimension i.e. ‘responsibility and attitudes towards safety’ including five items with their loadings illustrated in Table 3.

Table 3: Factor score for 1st dimension from 19 attitude items on road safety for the Ghanaian population (N= 286)

<table>
<thead>
<tr>
<th>Dimension 1: ‘attitudes towards responsibility and safety’</th>
<th>Dimension 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>If my friends were passenger of an unsafe driver, I would join them</td>
<td>0.73</td>
</tr>
<tr>
<td>In the absence of other good alternatives, I would let an unsafe driver drive me home</td>
<td>0.66</td>
</tr>
<tr>
<td>To maintain flow in traffic, one must ignore several traffic regulations</td>
<td>0.60</td>
</tr>
<tr>
<td>It is reasonable to ignore red lights when there are no other cars or people in sight</td>
<td>0.49</td>
</tr>
<tr>
<td>If a pedestrian is run down by a car, the pedestrian is to blame</td>
<td>0.46</td>
</tr>
</tbody>
</table>

However, the reliability of this dimension is not particularly high (Cronbach’s alpha 0.55, mean inter-item total correlation 0.20). This dimension explains 11.9% of the total variance in the items. This finding illustrates that ‘attitudes’ are complex phenomena with many facets which create difficulties in joining them together especially in African countries. This relatively modest result could be influenced by non-homogenous attitudes between the sexes, age groups and other underlying background variables in Ghana (e.g. education, income, social status etc). Lower mean values express a more favourable safety attitude.

As illustrated in Table 4, results from the analysis of the differences in means for the first attitude dimension by gender, age groups and education level show that there are highly significant differences especially by gender groups, with the strongest occurring between Ghanaian males (mean 7.83; SD = 3.41; N = 140) as against Norwegian males (mean 10.55; SD = 2.92, N = 96). It is interesting to note that the attitudes regarding responsibility and road safety in general are much more favourable in Ghana than in Norway and for both sexes as well. Regarding age groups, there are analogous differences in Ghana’s advantage for age groups concerning road safety attitudes.
Table 4: Mean score for dimension 1 ‘attitudes towards responsibility and safety’ by age groups for Ghana and Norway, 2006. Likert scale where: 1 = strongly agree & 5 = strongly disagree for 4 variables. (min. score: 4, max. score: 20)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Country</th>
<th>Mean</th>
<th>SD</th>
<th>P value for difference</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-25 years</td>
<td>Ghana</td>
<td>7.95</td>
<td>3.78</td>
<td>&lt;.01</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>10.24</td>
<td>2.81</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td>26-49 years</td>
<td>Ghana</td>
<td>7.87</td>
<td>3.41</td>
<td>.01</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>9.03</td>
<td>3.00</td>
<td></td>
<td>79</td>
</tr>
<tr>
<td>50-90 years</td>
<td>Ghana</td>
<td>7.68</td>
<td>3.13</td>
<td>.03</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>9.48</td>
<td>2.88</td>
<td></td>
<td>85</td>
</tr>
</tbody>
</table>

Combining sex and age, the strongest country difference is males between 17-25 years. We can also observe a tendency to report lower means (i.e. more favourable attitudes) among the Ghanaian population in the various education groups. Ghana’s attitude advantage seems to be reinforced by higher education. (However, education is not a significant predictor for risk attitude and behaviour measures (sum scores) in the country. Relatively it is strongest for college/university educated respondents in Ghana (mean 7.44, SD = 3.04, N = 142) vis-a-vis Norway (mean 9.15, SD = 2.85 N = 99). Small numbers reduce the power of statement of the unfavourable attitude score of presumably the most vulnerable group, i.e. road users with vocational education/training.

3.2.1. Explanation variables for the attitude related to responsibility and safety

Previous studies have shown various factors that may explain attitudes, however the results varies and are partly inconclusive (Assum, 1997; Laapotti et al, 2003; Iversen & Rundmo 2004). No cultural dimension from factor analyses turned out as giving a significant contribution to explain variation in attitudes in the two countries.

However, as shown in Table 5, some single items turned out to be significant for Ghana only. However, the validity and reliability of such single items can be questioned. Nevertheless they seem to illustrate some cultural characteristics of the driving pattern and style in Ghana (such as observing driving pattern, awareness of sounds, using the horn) in contrast to Norway.

Higher risk willingness represents clearly a negative attitude for safety and is more pronounced in Norway. Reliance on ‘destiny’ implies risk attitudes in Norway, but not in Ghana. Gender, age and sex were not significant explanatory factors in the Ghanaian material, whereas gender alone was significant in the Norwegian data, pointing to males as a risk factor (i.e. negative effect on responsibility and safety attitudes.)
Table 5: Linear regression model with factors influencing dimension 1 ‘attitudes towards responsibility and safety’ for Ghana and Norway, 2006.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Ghana</th>
<th></th>
<th>Norway</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place of residence (urban, semi-urban, rural)</td>
<td>-.149</td>
<td>.002</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>Cultural item 45</td>
<td>-.249</td>
<td>&lt;.01</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>More important to notice the behaviour of others in traffic than to look at road signs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural item 19</td>
<td>-.215</td>
<td>.03</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>If one does not follow ones inner voice, society will fall apart</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural item 28</td>
<td>.168</td>
<td>.01</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>When someone hunks their horn, I have done something wrong</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural item 27</td>
<td>.148</td>
<td>.02</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>While in traffic, I ‘m especially aware of the sounds around me</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural item 22</td>
<td>-.135</td>
<td>.04</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>If everyone followed their own conviction, traffic would run smoothly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk willingness (sum score 4 items)</td>
<td>-.120</td>
<td>.05</td>
<td>-.234</td>
<td>n. s</td>
</tr>
<tr>
<td>Destiny (sum score 6 items)</td>
<td>-</td>
<td>n. s</td>
<td>-.161</td>
<td>.02</td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>n. s</td>
<td>-</td>
<td>n. s</td>
</tr>
<tr>
<td>Education (4 levels)</td>
<td>.032</td>
<td>n. s</td>
<td>-.096</td>
<td>ns (.13)</td>
</tr>
<tr>
<td>Sex, females = reference cat.</td>
<td>-</td>
<td>ns (.24)</td>
<td>-.261</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Adjusted $R^2$ (N)</td>
<td>0.24 (N = 209)</td>
<td></td>
<td>0.13 (N = 226)</td>
<td></td>
</tr>
</tbody>
</table>

3.3. Attitudes related to drinking and driving

The second important factor dimension based on two items turned out to be attitudes related to ‘drinking and driving’. For this dimension the reliability was just slightly higher (Cronbach’s alpha 0.60, mean inter-item total corr. 0.43). The dimension explained 9.0 % of the total variance. The relatively low reliability shows that there are no distinct patterns for the attitude items when Ghana is taken as the basis country for the analyses, albeit it was not higher for the Norwegian data either.

Condensation of the results from comparing the means for ‘drinking and driving’ attitude for Ghana and Norway by gender, age and education showed the following: Ghana (mean 2.62; SD = 1.43, N=142) and Norway (mean 2.29; SD = 1.0, N=144). Norwegian females have significantly lower (i.e. more favourable) score. The only age group which shows significant difference is the 50-90 year group, with Norwegians reporting more favourable score. These figures could have been influenced by low numbers (87 respondents in Norway and only 19 in Ghana). On the other side of the coin, it is surprising to note that the elderly males in the Ghanaian sample express more unfavourable attitudes towards drinking and driving vis-a-vis the younger respondents. The distance between the youngest and oldest age group is remarkable, despite the fact that the number of 50-90 year males is small. This finding apparently contradicts earlier findings which note that younger males
judged the risk of dangerous traffic situations, such as drinking and driving, as lower compared to older males (Trankle et al. 1990; Lund & Rundmo, 2009). Concerning education, the lowest level (i.e. primary/secondary school) revealed differences between the 3.05 mean obtained for Ghana as against 2.00 mean obtained for Norway. This tells that all respondents here scored maximum value, even though fewer cases were considered in Norway (i.e. N=14) as against 79 for Ghana.

3.4. Risks-taking behaviour among pedestrians
Risk-taking behaviour involving vulnerable groups may emanate either from the vulnerable road user, for instance as an inattentive pedestrian on a road or through risk-taking attitudes of a recalcitrant motorist who ignores traffic regulations and cause injury risk and vulnerability. Two behavioural items were stated for pedestrians: ‘walking on roads with traffic after dark’ and ‘take risks in traffic’. Results from the analyses show a positive correlation in Norway (0.22 (p = .00) but a negative correlation in Ghana (-0.16 (p = 0.01). Table 6 further illustrates safety oriented pedestrian behaviour in both Ghana and Norway for both sexes. However, the system risks i.e. the risks associated with the road systems and the traffic environment may vary widely.

Table 6: Mean score on two items on pedestrian behaviour by gender, Ghana and Norway, 2006. 5-points scale where 1= very often – 5= never

<table>
<thead>
<tr>
<th>Item</th>
<th>Gender</th>
<th>Country</th>
<th>Mean</th>
<th>SD</th>
<th>P value for difference</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid walking on roads with traffic after dark</td>
<td>females</td>
<td>Ghana</td>
<td>2.97</td>
<td>1.37</td>
<td>.03</td>
<td>143</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>3.30</td>
<td>1.18</td>
<td></td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Ghana</td>
<td>2.97</td>
<td>1.35</td>
<td>&lt;.01</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>3.37</td>
<td>1.20</td>
<td></td>
<td>101</td>
</tr>
<tr>
<td>Take risks in traffic</td>
<td>females</td>
<td>Ghana</td>
<td>1.89</td>
<td>1.20</td>
<td>.02</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>2.28</td>
<td>1.06</td>
<td></td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>males</td>
<td>Ghana</td>
<td>2.16</td>
<td>1.26</td>
<td>n. s</td>
<td>141</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>2.22</td>
<td>0.87</td>
<td></td>
<td>101</td>
</tr>
</tbody>
</table>

Regarding age groups, the Ghanaian populations expressed a safer pedestrian behaviour for two age groups (17-25 and 26-49 years respectively) with significant national differences, but with no stronger safety behaviour with increasing age, as seen in Table 7.

Table 7: Mean score on two items on pedestrian behaviour by two age groups, Ghana and Norway, 2006. 5- points scale where 1= very often – 5= never.

<table>
<thead>
<tr>
<th>Item</th>
<th>Age groups (in yrs)</th>
<th>Country</th>
<th>Mean</th>
<th>Std</th>
<th>P value for difference</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid walking on roads with traffic after dark</td>
<td>17-25</td>
<td>Ghana</td>
<td>2.91</td>
<td>1.28</td>
<td>&lt;.01</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>3.49</td>
<td>1.06</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>26-49</td>
<td>Ghana</td>
<td>2.90</td>
<td>1.40</td>
<td>.01</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>3.39</td>
<td>1.26</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Take risks in traffic</td>
<td>17-25</td>
<td>Ghana</td>
<td>2.09</td>
<td>1.27</td>
<td>.01</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>2.50</td>
<td>0.86</td>
<td></td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>26-49</td>
<td>Ghana</td>
<td>2.07</td>
<td>1.24</td>
<td>n. s</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Norway</td>
<td>2.28</td>
<td>0.73</td>
<td></td>
<td>80</td>
</tr>
</tbody>
</table>

The evidence shows that there is a distinct difference in pedestrian safety behaviour in the Ghanaian population, especially for people with higher level of educational attainment, in
sharp contrast with Norwegians. Ghanaians clearly express more cautious behaviour, especially when walking on roads with traffic after dark (means 2.80, SD = 1.29, N=150 versus means 3.37, SD =1.12, N=101 for Ghana and Norway respectively).

3.5. Behaviour among motorised road users related to drinking and driving

Road user’s behaviour is also related to driving behaviour, which implies that the respondents have some driving experience. In Norway this is synonymous with being a motor vehicle license holder, whereas in Ghana the case is not so clear or obvious, by the very fact that license holding is not so strictly maintained. It is not uncommon for motorists to drive without valid drivers’ license, especially among commercial drivers. Thus, the proportion of license holders in the sample population is 31.0 % and 89.1 % in Ghana and Norway respectively. Nevertheless, the proportion stating traffic behaviour in the Ghanaian survey is 53.6 %. We therefore conducted a factor analysis using the Ghana data solely to uncover a first dimension from 27 behaviour items. The factor baptized ‘driving and drinking’ included 4 items, with a high Cronbach’s alfa of 0.82 and a mean inter-correlation of 0.55. The dimension is explaining 25.5 % of the variance in the 27 items on behaviour pattern in the questionnaire. The second dimension baptized ‘attentive and cautious driving’ including 5 items came out with a Cronbach’s alpha 0.76 and a mean inter-correlation of 0.35. The dimension is explaining 14.7 % of the variance. The result of the analysis, as illustrated in Table 8, is solely on the first factor.

Table 8: Mean scores for dimension 1: ‘drinking and driving behaviour’ by sex, Ghana and Norway, 2006. Likert scale where: 1 = strongly agree – 5 = strongly disagree, for 4 variables. (min. score: 4, max. score: 20)

<table>
<thead>
<tr>
<th>Gender</th>
<th>Country</th>
<th>Mean</th>
<th>SD</th>
<th>P value for difference</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>Ghana</td>
<td>18.42</td>
<td>3.45</td>
<td>.06</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>19.35</td>
<td>0.89</td>
<td></td>
<td>124</td>
</tr>
<tr>
<td>Males</td>
<td>Ghana</td>
<td>18.51</td>
<td>3.41</td>
<td>n. s (0.22)</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>18.93</td>
<td>2.92</td>
<td></td>
<td>96</td>
</tr>
</tbody>
</table>

The variance in these four items on a Likert scale range of 1 to 5 is restricted and 88.7 % of the total population has scores in the range 18-20; which is understandable for such a risk sensitive sum score.

Higher mean values express more positive attitudes (i.e. strongly agree) towards the safety issues indicated by the four items. The behaviour as well as the corresponding attitude regarding drinking and driving is less favourable for females in Ghana than in Norway. There are also significant differences between males and females within the Norwegian age groups but not for Ghanaians.

There were no significant differences in driving and drinking behaviour sum score for the age groups 17-25 and 50-90 years, partly due to small numbers in the subgroups. For the group 26-49 years the Ghanaian population reported stronger risk behaviour (means = 18.23, SD = 3.37, N=80 versus means = 19.33, SD = 1.05, N=72 for Ghana and Norway respectively).

Regarding levels of education, only the lowest level (i.e. primary/secondary school) uncovered differences between these two countries with Ghana obtaining the strongest risk reporting (mean= 18.77, SD = 0.47, N = 43) as against Norway (mean= 19.71, SD = 3.61; N=14). In Norway this education level is rarely found and it is usually associated with elderly people’s education.
3.5.1 Explaining behaviour related to drinking and driving

Factors explaining differences in the behaviour dimension ‘drinking and driving’ were performed by logistic regression (See Table 9 below). The values on the sum score and the dependent variable were skewed. In the score range of 18-20, we found 71.4 % and 77.8 % for Ghana and Norway respectively. These score ranges were used as the dichotomous cut values for the logistic model (value 18-20 =1; others =0). After running a multitude of logistic models, it turned out to be only one significant explanation factor: attitudes towards unsafe driving. The cultural factors failed to contribute directly to explain variance in behaviour (even if they where influencing attitude scores, as shown previously).

Table 9: Logistic regression model with factors influencing dimension 1: behaviour towards ‘drinking and driving’ for the Ghana population, 2006 (N=121).

<table>
<thead>
<tr>
<th>Logistic regression</th>
<th>OR</th>
<th>95% C.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum score (2 items) attitudes towards unsafe driver</td>
<td>0.74</td>
<td>0.58 – 0.94</td>
</tr>
<tr>
<td>Not significant:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (female = ref. group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It seems obvious that careful attitudes towards unsafe drivers dispose for favourable driving behaviour regarding drinking and driving, i.e. sober driving habits. Moreover, it is striking and consistent with prior findings in this study, that sex, age and educations are non-influential factors on the most important behaviour dimension in Ghana.

Several model running were performed solely on the Norwegian data to turn out with only two significant explanation variables: a sum score on destiny and one dimension on culture (from factor analysis) accentuating written material about danger and ‘what is right and wrong in traffic’ (including 3 items). The results of the analysis are seen in Table 10.

Table 10: Logistic regression model with factors influencing dimension 1: behaviour towards ‘drinking and driving’ for the Norway population 2006 (N=214).

<table>
<thead>
<tr>
<th>Logistic regression</th>
<th>OR</th>
<th>95% C.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culture factor on ‘reading about danger and what is right/wrong in traffic’ sum score (3 items)</td>
<td>0.76</td>
<td>0.63 – 0.92</td>
</tr>
<tr>
<td>Sum score destiny (6 items)</td>
<td>0.89</td>
<td>0.82 – 0.96</td>
</tr>
<tr>
<td>Not significant:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (female = ref. group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Despite running numerous models, the model fit is modest for both linear regression and logistic models respectively. Clearly unexplained variance is substantial. The regression analyses emphasize the point that it is difficult to establish a clear relationship between culture traits, attitude variables and behaviour regarding road safety. The second dimension ‘attentive and cautious behaviour’ with potential explanation factors was analysed by a linear regression model with relatively poor explained variance (Adj. R² =0.13, (N=226) and 0.09 (N=94) for Norway. It seems that there are stronger relationships and structures in the Norwegian material than the Ghanaian data regarding this behaviour dimension – even if it is constructed from the Ghanaian data set only. In the Norwegian material, we analysed the influence of background variables such as sex, age and education on attentive and cautious
behaviour. It is weaker for males as compared to females, and stronger for the elderly people. However, higher education predicts lower attentive and cautious behaviour. This seems to be a paradox, but could partly be explained by an increasing perception of personal control of ‘the environment’ that comes with higher education.

4. DISCUSSIONS
There are several distinct differences between the Ghanaian and the Norwegian sample population, in particular regarding risk perception and safety-oriented attitudes and behaviour. On the whole, the patterns persist when the data is stratified or controlled by gender, age groups and education.

When gender is taken into consideration, Ghanaian males judge the injury probability highest. This phenomenon could be attributable to differences in cultural practises between the two countries. In Ghana, males are generally seen as bread winners of the family. Consequently, it behoves them to undertake several ventures to make ends meet which may bring them into direct contact with life-threatening circumstances, such as traffic accidents. As society’s expectation of them increases and the pressures to eke out a living become unbearable, most males adopt offensive and sometimes aggressive attitudes and behaviour in public. This could transmit to other spheres of society, such as males’ reckless behaviour on the roads. Again, by being repeatedly exposed to risks, research has shown that peoples’ perception of these risks often diminishes (Gleitman, 1995); people’s behaviour becomes more complacent and less careful of potential threats. Thus, serious injury or fatality is often the result in the medium and long term. Moreover, masculine tendencies in most Ghanaian males often make them reckless and tend to ignore safety or precautionary measures. As a direct function of the above-noted factors, the ‘risk culture’ becomes endemic to males especially.

Again, for the various age groups, it appears that adolescent males are less sensitive to risks and they tend to underestimate the probability and severity of risks caused by traffic situations compared to elderly people and females. This finding is corroborated on by a recent publication that for the period 2000-2007, the active age group (i.e. 16 – 45 years) were the most vulnerable in road traffic fatalities representing 57.8 % of the total fatalities and that these fatalities were mostly among pedestrians and bus/minibus occupants (Republic of Ghana, 2007). It should be noted, however, that the situation could be worse and that the real percentage of fatalities could exceed the above-stated figure. In Ghana, as in many developing countries, there is the problem of under-reporting of the actual number of casualties which could be as a result of outright non-reporting of accidents to the police and the hospitals or under-recording due to incomplete retrieval of reported accident cases from police records.

Owing to the huge differences in the general education systems, is difficult to compare between the two countries on the basis of levels of educational attainment. Again, enhanced education does not seem to have a positive and systematic road safety inducing effect. The term ‘general education’, as used here, is not to be confounded with driver education but formal education. Education may increase general knowledge but rarely results in appropriate behavioural change. Education or training for driving is an entirely different aspect from the more formal type of education. In Ghana, most motorists, especially drivers of minibuses, locally referred to as trotro are either oblivious of the road traffic regulations or totally disregard highway codes and road signs with impunity. They also neglect their inner sense of adequate and safe driving. This could be blamed partly on the scant driving schools and institutes to train professional drivers in the theory and practise of defensive driving. Most drivers obtain their skills through apprenticeship with senior drivers, most of whom have little or no education at all.
As a result, their awareness of sounds could, for instance, be indications of committing faults or traffic rule violations, and hence interpreted as favourable safety attitudes. Motorists in Ghana could drive on the shoulders of the road to avoid traffic jams; stop abruptly or slow down in the middle of moving vehicular traffic to allow prospective passengers to embark or disembark and sometimes could even jump red traffic light signals, probably due to the insufficient number of police personnel (Agyemang, 2009). These irresponsible driving attitudes pose danger to vulnerable road users. However, road users in Ghana who had attained higher education are extremely cautious and mindful of the pedestrians’ position in the road system. The highest scores on risk perception and most favourable scores on risk-taking attitudes and behaviour were found in the Ghanaian sample, except for drinking and driving. Age and gender do not make an influence on differences or as predictors on safety attitudes and behaviour, except for safety attitude in Norway.

Furthermore, a general conclusion may be that education does not, in general, help that much in reducing risk taking behaviour whether in Norway or in Ghana. This could be attributable to enhanced feeling of being in charge of one’s milieu which usually comes with higher education level. Since there is a lack of good evidence on the effectiveness of safety education, other conditions influencing injury risk within the social environment, such as cultural traits, should be considered as well. From the linear regression analyses, there are some clues that Ghanaians generally respond to sounds and reading the intentions and behaviour of other road users rather than strict adherence of the formal road traffic regulations in the form of highway codes and road signs. Thus, honking of horns by motorists, for instance, is an essential part of the negotiating processes and manoeuvrings between them and vulnerable road users in the road environment. Our personal observations have also revealed that pedestrians occasionally have had to virtually plead with motorists to enable them cross the road even when zebra crossing markings have clearly been delineated at those places where the pedestrians stood; in a clear scenario of the survival of the fittest.

Ghana is partly pervaded by risk taking behaviour, inattentive behaviour and the general stress level in the society, cultural traits about ‘getting on’ and ‘going places’. The road environment is compact with mixed road users and street activities by the informal economy in which traders or hawkers trade in different wares on major roads and junctions. It is said that the first law of the informal economy states that ‘opportunities to make money must be exploited when and where they occur, regardless of whether officiandom approves’ (Stock 2004, p.263). These hawkers quickly rush to any moving vehicle that stops or slows down due to traffic light signage with the view to plying their trade. They thus compromise on their personal safety by focusing all their attention on their prospective customers. More often than not, they are involved in serious injuries or fatalities.

In the early post-war period, Smeed (1949) stressed the inverse association between road fatalities and national wealth and how economic growth could benefit road safety. This association is partly related to the extent countries could afford physical safety efforts like traffic separation and safer ways of organising road activities, and partly related to the public acknowledgement of non-accept of the toll of the road and need for more enforcement and safety measures. In the wake of this consciousness, laws and safety regulations to protect vulnerable road users are launched. Ghana is on its way in this social and physical infrastructure transformation.

5. STRATEGIES AND EFFORTS TO IMPROVE ROAD SAFETY

Obviously a very substantial fraction of the traffic injuries involving vulnerable road users are related to human errors, risk taking, erroneous risk judgement, aggressive driving, inattention and other types of inappropriate behaviour among various road users. Consistent with the argument that it is possible to change behavioural patterns through influence of risk
perception (Rundmo, 1999), holistic intervention measures must be put in place at the micro, meso and macro levels respectively.

At the micro level, the individual and the society as a whole must be encouraged to take personal responsibility while in traffic. Massive, well-publicised and sustained road traffic educational campaigns may in the long run achieve appropriate changes in cultural norms and perceptions of risks in traffic. For instance, the Ghana NRSC’s attempt to inculcate road safety into the formal academic curriculum for school children as well as other mass education for the general public are seen as best practises which could lead to a positive change in road traffic norms and behaviour. The NRSC also needs to step up on its other road safety public awareness initiatives, such as the Seat Belt and Crush Helmet Campaign; Campaign on Fatigue and the Campaign on Drink Driving etc which are already yielding some positive responses.

In addition, a cost-effective measure will be that children and other pedestrians in low and middle income countries must use reflex discs when they walk in the dark. The setting up of more formal driving schools to educate motorists on issues such as defensive driving and impression of respect for vulnerable road users must be embraced.

Information and behavioural change are best passed on from a person’s close friends and family members. Thus, at the meso level, communal advocacy efforts, for instance the Arrive Alive campaign in Ghana will engender the diffusion of road safety awareness among community members. Coupled with the above, the introduction of pavements for pedestrians to walk separately from motorised traffic –especially at high-risk crash sites –and other area wide traffic calming measures by stakeholder institutions of the Ghana National Road Safety Commision, though limited in scope, seem to be best practises to reduce pedestrian injuries and the project must be expanded. Before- and-after investigation of the introduction of speed bumps in Ghana showed a 55 % reduction in all deaths and a 51 % annual reduction in crashes in which a pedestrian was hit (Afukaar, 2003).

Many of the proposed macro strategies on traffic safety have been developed primarily from the perspective of preventing injuries to vehicle occupants only, with less consideration to their effect on vulnerable road users as bicyclist and pedestrians (Ameratunga et al, 2006). However, other studies have shown that not all policies and campaigns, even those enacted with the best of intentions, are perceived to be beneficial by vulnerable road users in low and middle income countries. For instance, evidence from Mexico (Hijar et al, 2003), Brazil (Forjour, 2003) and Uganda (Mutto et al, 2002) reveal that pedestrians will not walk long distance to use overpasses, which are also perceived to be high-risk milieu for violent crimes. Thus, pedestrians will create their own routes through the traffic in spite of the associated risks.

While addressing peoples’ perception of overpasses by improving security and adequate lighting during night times, city authorities in low and middle income countries must take bold and decisive actions, at the macro level, to ensure strict compliance to legislations concerning road safety. Ghana already has ample legislations concerning speed limits, use of seatbelt in rear seats, child restraints, helmet use and drink driving but these are seldom enforced. Evidence from parts of Accra, where the fixing of barbed wires on dwarfed walls separating the lanes of major highways by the city authorities coerced pedestrians to use near-by overpasses, prove that when local authorities are adequately resourced and empowered to regulate human traffic behaviour, road users will behave accordingly.

Enforcement of existing legislation frameworks on traffic safety must be done with appropriate sanctions and penalties for infringement. This must be done in a well-publicised and sustained manner as well. This will increase the perceived likelihood of being detected and penalized. The police must be equipped with the requisite logistical support to carry out more random breath-tests and to set up adequate checkpoints which are important
enforcement mechanisms to reduce alcohol-related crashes. Again, incentive packages for promoting and rewarding good behaviour while in traffic must be encouraged by all stakeholders.

REFERENCES


BICYCLE HELMETS, RISK COMPENSATION AND CYCLIST TYPES

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ABSTRACT
A few countries have legislated compulsive bicycle helmet use. The evidence from these countries concerning the effect of mandatory helmet use is mixed. Both risk compensation effects and changes in cycling population due to helmet legislation have been put forward as explanations regarding the lacking effect from before and after studies. As risk compensation normally is related to accident reduction measures, not injury reducing measures, the case of helmet use is an interesting case to further our knowledge on this important topic. In order to learn more about the relationship between helmet use, accidents, and cyclist typology, a random sample of 5000 participants were drawn from the Falck National register of bicycle owners in Norway. The respondents were approached via email. Due to non-existent mail addresses etc, the final sample consisted of 3930 persons who received invitations. The results of the study showed that “speed happy” cyclists seem to be involved in more cycling accidents. The use of bicycle helmet as such does not seem to be related to either accident-proneness or speeding. However, the helmet is typically seen as a part of a package of equipment that is typical of the speeding (and accident involved) cyclist. Data on risk perception collected in the questionnaire gives further insight into these quite intricate relationships.

1 INTRODUCTION
1.1 Lack of effects of helmets in legislation

As yet, only a few countries have legislated mandatory bicycle helmet use as a measure, but several countries are considering introducing helmet laws. What would be the effect of such a law? Would fatality rates be reduced?

Most case-control studies show injury reducing effects of bicycle helmets, as has been summarised in several reviews (Attewell, Glase, & McFadden, 2001; Thompson, Rivara, & Thompson, 2000). These results mainly come from cross sectional studies of helmet users vs non-helmet users. However, the evidence from countries that have introduced helmet laws is mixed. Some studies report that head injuries among cyclists have been reduced following the helmet use law (Carr, Skalava, & Cameron, 1997; Hendrie, Legge, Rosman, & Kirov, 1999). Other population studies show that these reductions are not larger than for other road user groups (i.e. other accident reducing mechanisms than the helmet are at work) and that the reductions over time in other injuries are even larger than the reductions in head injuries (Robinson, 2006). This has been seen as an indication that the main reason for the reductions is reduced cycling and not an effect of the helmet. Furthermore the case-control findings are...
often criticized for not having sufficient control for other factors, i.e. that there are many other factors that differ between cases and controls in these studies, and that the effects are related to these factors and not to helmet wearing. Robinson (2007) shows that lack of effects from helmet laws seem to be the rule rather than the exception.

1.2 Risk compensation?

The explanations given in population studies for why helmet laws do not work as intended are most often risk compensation; i.e., that cyclist with helmets cycle faster and more risky (Robinson, 2006). The reasoning is that people perceive risk to be lower when wearing a helmet (than not wearing a helmet), and compensate for this perceived decrease in risk and increase in safety by cycling faster and more aggressively. The issue of risk compensation connected with helmet use has been the focus of a quite heated debate within the research community, see e.g Adams and Hillman (2001) and www.cyclehelmets.org.

An important question in the discussion about risk compensation of safety devices is: “why are some devices or measures compensated and others not?” A traditional assumption is that intervention has to be either intrusive or conspicuous in order to be compensated. However, some researchers also claim that there is a distinction between injury reducing and accident reducing interventions, and that normally only the latter are compensated (Bjørnskau, 1995; Graham, 1982; Lund & O'Neill, 1986; OECD, 1990; Sagberg, Fosser, & Sætermo, 1997) (Bjørnskau, 1995; Lund & O'Neill, 1986; Sagberg, et al., 1997). The bicycle helmet is not an accident reducing device and hence should not “fall victim” of risk compensation. However, it can be argued that the accident/injury distinction makes less sense for the bicycle helmet than it does for a typical safety device for cars, such as ABS-brakes. As a cyclist the perceived difference between being in an accident and having an injury is rather small, whereas for a car driver an accident may not necessarily imply being injured due to the protection inherently offered by the mass of the car. It has been argued that if the ratio of personal injury to non-personal injury is large also injury reducing measures will be victim of risk compensation (Bjørnskau, 1995; Fridstrøm, 1999). Thus it might well be that the helmet is potentially the subject of a risk compensation mechanism.

1.3 Population shifts?

Another explanation why helmet laws do not seem to give the results hoped for could be that the cycle population shifts as a response to the law. Helmet laws generally reduce the number of cyclists, and if the cyclists remaining after the introduction of a law are the ones behaving most risky it is not surprising that the law does not give the expected result. In particular there will be a decrease in traditional cyclists, who don’t have many accidents anyways. Indeed, it could also be that the helmet law is introduced as a response to increased cycle accidents – which again could be related to changes in the cycle population towards a more training oriented type of cyclists with fast cycles and special equipment, including helmets. If so, a helmet wearing law would only boost such a trend.

According to the risk compensation hypothesis one should expect helmet users to cycle faster than non-users, but not to perceive the risk of a bicycle accident to be different from non-wearers. By using the helmet, they initially perceive risk as being reduced, but cycle faster so as to compensate for this effect.

By contrast, the population shift hypothesis implies that the average cyclist behaves more risky after a mandatory helmet wearing law is introduced, because it is the most risky cyclists that remain in the population after helmets have become mandatory. In a situation where a
helmet wearing law is not yet introduced, we expect helmet users to perceive risk as being greater than non-users. This is mainly due to the fact that helmet wearing is part of a equipment “package” suitable for training and fast cycling. However, there might also be another subgroup of cyclists that voluntarily wear helmets because they are particularly safety oriented, and not because the helmet is part of a larger equipment package.

1.4 Aims and objectives

Both the risk compensation hypothesis and the population shift hypothesis suggest that helmet users will cycle faster than non-users. Risk perception will, however differ systematically between users and non-users according to the population shift hypothesis, but not according to the risk compensation hypothesis.

To our knowledge there are no studies that have systematically investigated risk perception as such among different groups of cyclists, and especially not helmet users vs others. The purpose of the present article is to investigate whether the lack of effect of helmet wearing laws is due to risk compensation mechanisms or population shifts, by looking at risk perception, cycling behaviour, accident involvement and use of various cycling equipment.

By exploring the causal pathways between risk perception, cycling behaviour, helmet use and accident involvement the study aims at shedding light on the viability of these two explanatory models.

1.5 Bicycle helmet use in Norway

In Norway helmet use is not mandatory. In 2006 a motion was put forward for introducing a helmet law for children under the age of 16, but this was thrown out by the national road authorities as their own research concluded that this would reduce the bicycling activity in this age group with 9 percent (Gidske, Grendstad, & Nordtømme, 2007). The use of bicycle helmets has been annually registered through behaviour observations on counting stations since 1999. In 2008 39 percent (35 percent females and 41 percent males) of passing bicyclists above 17 years of age in eastern Norway used a helmet (Muskaug, Nygaard, Rosland, Johansen, & Sjøvold, 2009).

2 METHOD

2.1 Sample and procedure

A random sample of 5000 participants was drawn from the Falck National register of bicycle owners in Norway. The respondents were approached via email. Due to non-existent mail addresses etc., the final sample consisted of 3930 persons who received invitations during September 2008.

A total of 1504 respondents participated in the study, i.e., a 38 percent response rate. 63 per cent of respondents were males, 37 per cent were females. The age ranged from 16 to 65 years (M=43, SD=9.21). The sample is biased compared to the Norwegian population. People between 20 and 49 years and people holding a university degree are overrepresented in the sample (79 per cent of the respondents held a university degree).
2.2 Measures

The questionnaire started with questions regarding frequency of bicycle use, ownership and frequency of helmet use and ownership and frequency of use of other bicycle equipment (cycling jacket, cycle trouser, cycling glasses, cycling computer). Accident involvement was measured by a series of questions concerning number of accidents, severity of accidents and how recently the last accident had happened. The respondents were also asked to state their degree of agreement (from 1 to 7) on four items concerning how fast they cycled and how competitive they behaved when cycling.

Risk perception was measured as “how large do you believe the risk is for you to be involved in an accident when you are out cycling”. Feeling unsafe was measured as “to what degree do you feel unsafe when you are out cycling”. Probability was measured as “how probable do you think it is that you will be involved in an accident when you are out cycling”. Consequence was measured as “if you were to be involved in an accident, how serious do you think the consequences would be?” All items were to be scored on 5 point Likert scales.

3 RESULTS

3.1 Cycling frequency and helmet use

On the face of it, the sample seems to be more “eager” cyclists than the average population: 31 percent reported that they “normally” use their bicycle more than 5 times a week, and as many as 30 percent report to “normally” cycle even in wintertime. If we look at the number of respondents who reported to have used their bicycle on the day prior to answering the questionnaire we find that 44 percent of the respondents in the current study had one or more bicycle trips. Data from the national travel survey (Vågane, 2006) show that 11 percent of the population had at least one cycling trip the previous day in September. This confirms that the respondents of the survey have a cycling frequency that is far higher than for the average population of Norway.

89 percent of the participants had a bicycle helmet, and 54 percent claimed that they use it all the time. In a survey about attitudes and behaviour in traffic in Norway (Phillips & Fyhri, 2009) 33 percent of the respondents (people who cycle more than once a month) claimed to always use a bicycle helmet.

Table 1 shows the bivariate relationship between use of bicycle helmet (% always using helmet) and some selected variables. All the included variables except accident involvement and degree of neuroticism are significantly correlated with helmet use. The relationship between use of other types of cycling equipment and use of bicycle helmet seems to be particularly strong.

Table 1: Independent variables included in the structural equation model with coding. Bivariate relationships with bicycle helmet use (% always using helmet). Variables in italics are interval level in the SEM analysis but are recoded into categorical for ease of presentation.
If we explore this relationship further (see figure 1) it becomes apparent that a large proportion (65 percent) of those who never or seldom use bicycle helmet do not use any other types of cycling equipment. Among the helmet users there is a quite large proportion (35 percent) who uses all the other types of relevant equipment (cycling jacket, cycle trouser, cycling glasses and cycling computer).

![Figure 1: Use of other types of bicycle equipment for helmet users (sometimes, often or always) and non-users (never or seldom) (N=1389). Percent](image)

3.2 Multivariate analysis

In order to isolate the effects of different independent variables we use structural equation models (SEM) by use of the software package AMOS 16.0. There are two components in a structural equation model, the measurement model and the structural model. The measurement model describes relations between latent variables, and can be compared to
what is done in a traditional factor analysis. The structural model concerns the relationship between observed variables. The use of a structural model allows the estimation of both indirect and direct effects. Thus, SEM can perform factor analysis, multiple regression analysis and path analysis simultaneously.

Due to missing values, the sample size for these models are lower (N=1339) than the total sample (N=1504).

3.3 Measurement models

A confirmatory factor analysis was performed on 8 items pertaining to different types of bicycling behaviour. The model is not presented. Traffic violations consist of three manifest variables: “Red lights”, “One-way” and “Walk on zebra”. “Red lights” and “One-way” measure whether or not cyclists cycle against red traffic lights and against one-way traffic. “Walk on zebra” is a measure of the degree to which cyclist get off their cycle and walk over zebra crossings to cross a road. To cycle over zebra crossings is strictly not a violation in Norway. However crossing cars are not obliged to give way to cyclists at zebra crossings but they are obliged to give way to pedestrians at zebra crossings. So if a cyclist gets off the cycle, he is by definition a pedestrian and entitled the right of way at zebra crossings.

Another separate confirmatory factor analysis was performed on 4 items measuring risk perception. The model is presented in figure 3. The chi square/degree of freedom ratio test indicated that the model almost perfectly fits the data, the $\chi^2$/df ratio is 0.2. The model suggests a one-factor solution were the item “unsafe” has the smallest path estimate (0.37) indicating that the factor risk perception has less to do with emotional aspects of risk perception than with more cognitive evaluations.

3.4 Final structural model

In our final structural equation model we tested how the three factors risk perception, traffic violations and bicycle speeding influences level of helmet use and accident involvement.

The chi square/degree of freedom ratio is normally used to assess model fit in large scale samples such as ours (Jöreskog, 1969). A rule of thumb is that this measure should be less than two times its degrees of freedom (Hu, Bentler, & Hoyle, 1995). For the presented model the $\chi^2$/df ratio is 1.43, which is well within acceptable levels. The model is presented in figure 2.

For ease of presentation error terms and covariance paths, as well as indicator variables are left out of the model.

Figure 1 showed a very clear bivariate relationship between the use of bicycle helmets and the use of other types of equipment. This relationship is confirmed in the SEM model as the covariance between the error terms of these two variables was 0.28 (standardized estimate, not displayed). There is a strong relationship between fast cycling and use of equipment (standardised path estimate=0.57). Cycling frequency is also positively related to use of equipment (standardised path estimate=0.11). Traffic violations on the other hand is negatively related to equipment use (standardised path estimate=-0.22) and helmet use (standardised path estimate=-0.20). Being a fast cyclist is positively related to helmet use (standardised path estimate=0.24).

The only variable that has any substantial relationship with accident involvement is cycling fast; cyclists who like to cycle fast have had more accidents (standardised path
estimate=0.16). There are also positive links between Frequency and accidents and between Equipment and accidents, but these are rather weak.

Perceived risk is positively related to using a helmet (standardised path estimate=0.41) and using equipment (standardised path estimate=0.10). There is a separate path from “probability” to helmet use (standardised path estimate=-0.17).

![SEM model with standardized path estimates](image)

Figure 2: SEM model with standardized path estimates. Error terms, covariance paths, non-significant paths and paths with estimates <.10 have been removed from the model.

4 DISCUSSION

4.1 Risk compensation or population shift?

The main objective of this article was to investigate if lacking effect of helmet legislation could be due to a population shift theory or due to risk compensation effects. The analysis of responses from 1339 cyclists by the use of a SEM model showed that the variable that had the strongest correlation with accident involvement was “fast cycling”. Speed happy cyclists seem to be involved in more cycling accidents. The use of bicycle helmet as such does not seem to be related to accident-proneness.

On the other hand, the positive relationships between equipment/helmet use and fast cycling indicate an indirect effect of the helmet on accidents. In other words, by using helmet and other equipment some cyclists race even faster than they would have done without, and thus get involved in more accidents.

The topic of causal directions deserves some discussion at this stage. The proposed model suggests that “being a fast cycler” leads to a higher level of equipment use. This makes sense, as it is normally accepted that who you are defines what you do to a larger extent than the opposite. However, it can be argued that the latent variable described as “being a fast cycler” is not a description of who the cyclist is, but of what he or she does. After all, the variable is composed of a series of items describing specific behaviours, as is quite normal in psychological research. If this is the case, then it would also make perfect sense to say that using bicycle helmet/equipment leads to faster cycling behaviour, as is suggested by risk
compensation theory. The data utilized in this analysis are cross-sectional so we can never be certain that the causal paths follow the directions that we have proposed. However, the pattern of relationships in the structural model does strongly suggest that fast cycling precedes helmet and equipment use rather than vice versa.

The differentiated effects of helmets and cycling equipment also lend support to such a conclusion. Being a fast cycler is much more related to using non-safety equipment (shoes, jacket and computer) than safety equipment (a helmet). Thus, the fast cycling behaviour is less likely to be the result of compensating for a safety device, but more likely to be the result of having a desire to cycle fast and as a consequence of this having bought speed-improving equipment.

Thus, the results support the hypothesis that a lacking effect of helmet legislation is most likely a result of a population shift effect, and does not lend support to the risk compensation theory.

4.2 Risk perception among different types of cyclists

The relationship between risk perception and the other variables in the model is rather complex, and a bit difficult to interpret. The general finding is that risk perception is positively related to helmet use, both directly and indirectly via fast cycling. The path estimate from the latent variable “risk perception” to equipment use is far lower than the path from risk perception to helmet use. In other words cyclists who perceive the risk of an accident as high are somewhat more likely to use other equipment, but the likelihood that they will use a helmet is much larger.

The positive path between risk perception and fast cycling indicates that some cyclists rightly perceive the danger of being involved in an accident as higher than others, because of their own cycling behaviour.

The separate paths between probability (negative) and “feeling unsafe” (week, positive) and helmet use indicates that cyclists who use helmet but no other equipment are of a more timid type than the others but that they also consider their own risk of being involved in an accident as quite low.

In sum these results may indicate that several mechanisms are at play. Some people cycle fast and acknowledge that this leads to an increased risk. To alleviate the risk and also to be able to cycle faster they use cycling equipment, including helmet. Another group of cyclists, approximately 25 percent of our sample, put on a helmet because they are afraid of being involved in an accident. For this group their fear is unrelated to the speed with which they cycle, and their likelihood of being involved in an accident is no larger than for the average cyclist.

4.3 Differentiated effect of violations and fast cycling

The results of the factor analysis and the measurement model indicated a distinction between “fast cycling” and “traffic violations”. The distinction between these two types of behaviour is more clear-cut for bicyclists than for car drivers, as cycling fast on a bicycle is not a violation (i.e. bicycles can rarely achieve speeds above the speed limit).

The results of the SEM analysis indicated a differentiated effect of these two latent variables in the model. Whereas fast cycling is positively related to helmet/equipment use, violations show a negative relationship with these two variables. Further, violations are not related to risk perception and not to accidents. It could be argued that the lacking relationship between violations and accidents may have to do with cycling environments. Traffic
violations for cyclists typically occur in urban environments, were amenities such as red lights and one-way streets exists. In the current dataset cyclists who live in typical urban environments reported to do more traffic violations than cyclists from more rural environments. However, the inclusion of the “rural/urban” variable into the model does not increase the correlation between violations and accidents.

The analysis is based on the cyclists’ self-reported involvement in accidents with a bicycle. Previous research has found that the correlation between self-report data and hospital register data for motor vehicle injuries is actually quite high (Begg, Langley, & Williams, 1999). However, there might still be some systematic variation in people’s tendency to report accidents, and this systematic variation may influence the results obtained in the SEM analysis. A study conducted by Langley et al (2003) found that the tendency for under-reporting of hospital data of accidents varied systematically with age (children’s accidents are less under-reported), ethnicity, injury severity and length of hospitalization. There are to our knowledge no studies that have looked at systematic under-reporting in self reported accident data. The results should be treated with this as a potential source of error.

The portrayal of different groups of cyclists are of course somewhat caricatured. There are also other subgroups and variations of the existing groups, e.g urban cyclists, without helmets and cycle equipment that typically ride against red lights and one-way traffic – and thus commit violations but without any accidents due to low speed. It should also be noted that the sample in this survey is rather biased as it has a disproportionately high number of the “eager” cyclists and helmet users compared to the average population. Thus, it is likely that the first group is overrepresented on behalf of other types of cyclists. Future research should aim at reproducing these results in a more representative sample of cyclists.

4.4 Conclusion

The results show that the cyclist population in Norway broadly consists of two sub-populations: one training-oriented speed-happy group that cycle fast and have lots of cycle equipment including helmets, and one traditional, old-fashioned kind of cyclists without much equipment, cycling slowly. In the latter group it seems like the most careful and unsafe wear helmets.

The results of this study indicates that the lacking effect of helmet legislation most likely has to do with a population shift effect, in which the introduction of mandatory bicycle helmet wearing will lead to a decrease of traditional cyclists in the cycling population, who do not have much accidents anyway, whereas the speed-happy helmet- and equipment using cyclists will remain.

The results give less support to a risk-compensation explanation, in particular because the speeding behaviour of the speed-happy group is more connected to other types of equipment than bicycle helmets. The helmet is more or less just one element in the total equipment package. So it is not because of the helmet that these cyclists ride fast; they use all the equipment (including helmets) because they want to ride fast.

However, as these results are based on cross-sectional data, further studies using longitudinal data on cycling behaviour, equipment use and risk perception is needed in order to resolve some of the issues concerning causal directions between the variables.

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REFERENCES
CRITERIA FOR AGE BASED DESIGN OF ACTIVE VEHICLE SAFETY SYSTEMS

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ABSTRACT
In Criteria for age based design of active vehicle safety systems the recent results of the research project Evaluation of active vehicle safety systems and components in regard to their safety impact on elderly car drivers are presented. The project is funded by the Federal Highway Research Institute (BASt). The project aims to answer the question whether Advanced Driver Assistance Systems (ADAS) are able to support elderly drivers to stay mobile and, if so, how they need to be designed to do so. The aim of the project is to retrospectively develop a list of criteria which shall help to develop future age-based designs of driver assistance systems. Therefore an extensive market analysis was carried out at first. The market analysis contained a literature research, a survey with 70 elderly people and expert interviews. In the second phase test drives combined with special workload assessments were conducted.

1 INTRODUCTION
Today, the car is the most important vehicle for the maintenance of mobility for elderly people. Most elder drivers suffer age based constraints, light bad sight or hearing or decreasing flexibility and muscular strength. To compensate these age based constraints, elderly drivers develop strategies like reducing their driving speed or choosing light traffic routes. (Reschnar, Schlag 2002) However, not every constraint can be compensated this way and with a growing population of elderly drivers in most industrial societies, new solutions are needed to keep elderly people mobile and safe in their everyday life. The efficiency of drive support can be raised if criteria for age based design are considered in the development process of Advanced Driver Assistance Systems (ADAS).

The research project Evaluation of active vehicle safety systems and components in regard to their safety impact on elderly car drivers analyzes, whether driver assistance systems can support elderly drivers to stay mobile and therefore participate in everyday traffic safely. In this project several ADAS are tested, which shall help to compensate physical, sensorial and cognitive constraints of elderly drivers. The aim of the project is to retrospectively develop a list of criteria which should help to develop future age-based designs of driver assistance systems. Therefore the project focuses on serial ADAS and their impact on the road safety of elderly drivers.

The project is funded by the Federal Highway Research Institute (BASt) and follows an interdisciplinary approach in cooperation of automotive engineers and social scientists of the RWTH Aachen University.
In addition to an extensive market analysis, a requirements analysis was carried out. This
contained a literature research, a survey with 70 elderly people (55 to 82 years old) and expert
interviews. The requirements analysis’ aim was to collect data about the attitude of elderly
people towards ADAS, their mobility behavior, their driving habits and the constraints and
risks which elderly drivers face in everyday traffic.

In the second phase of the research process test runs where be held on a test track to
evaluate the effects of ADAS on the driving behavior and the road safety of elderly drivers.
Therefore a group of 30 probands (older than 65 years) and a control group (30 to 55 years)
were interviewed regarding their attitude towards the driver ADAS and their stress during the
driving maneuvers. The gathered data will be compared with the performance data of the
vehicles in order to identify generally valid criteria for age-based designs of active vehicle
safety systems.

2 SCREENING OF ELIGIBLE ADVANCED DRIVER ASSISTANCE
SYSTEMS AND ELEMENTS

2.1 Market analysis
At the beginning of the project a comprehensive market analysis of existing active vehicle
safety systems e.g. anti-lock braking system, anti-slip regulation, brake assistant, active
steering, etc. was performed. The market analysis showed the potential of existing and newly
developed driver assistance systems regarding their effects on road safety for elderly drivers.

2.2 Requirement analysis of elderly people regarding advanced driver
assistance systems
While in most industrial societies life expectancy increases, mortality and fertility rates
decrease. In the long term that leads to two major changes in the social structure: First to a
shrinking population, and secondly to a growing proportion of elderly in the population. In
Germany, as in most OECD countries, one third of the population will be older than 60 years
in 2030 and the percentage of the population aged 80 and older will triple until the year 2050.
(Engeln, Schlag 2008). Investigations revealed that increasing participation in the traffic and
the growth of the population of elderly people since 1998 led to a growing total number of
elderly casualties per year (Statistisches Bundesamt 2006). In comparison with other age
groups, elderly people have a lower accident rate (Statistisches Bundesamt 2007). The
Consideration of the risks of accidents in relation to the driving performance shows a clearly
different result. It turns out that those elderly who still drive cars, have a higher accident risk
than middle-aged groups (Statistisches Bundesamt 2007). The car’s importance for elderly
people is increasing, because the present group of elderly people is the first group to possess a
driving license for almost their whole life. According to that, it can be assumed, that with
increased mileage, the number of accidents will rise. Regarding the severity of the accident, it
can be noted that accidents of elderly people are significantly more likely to have fatal
consequences than those of younger people (Vorndran 2007).

The results of the requirements analysis demonstrate that elderly drivers account the car as
the most desirable mean of transport (Chaloupka 1994). They also revealed that the risk to
cause accidents in road traffic is higher for elderly people the fewer kilometers they drive
(Kütting, Krüger 2002). The survey we carried out within the requirement analysis showed
that many of the elderly drivers are aware of this risk and their constraints and are willing to
use driver assistance systems to increase road safety. Especially informational and warning
systems were perceived as helpful and got little rejection by the interviewed persons.
3 RESEARCH DESIGN AND REALIZATION

In the second phase of the research process test runs were carried out on a test track to evaluate the effects of ADAS. Therefore a special research design was developed which will be presented in this chapter.

3.1 Advanced driver assistance systems

The market analysis showed that there is a variety of ADAS, that is different in its functioning, its interaction with the driver and in its objective (e.g., increase safety, comfort, etc.).

The age-related changes suggest the conclusion that especially those ADAS which support the drivers independently, without requiring the drivers attention, and contribute to the reduction of the complexity of the driving task are suitable for elderly people.

For the further course of the project, in consultation with the project funder (BASt), brake assistant, brake assistant plus and active steering were chosen for closer examination with elder probands on the test track. These are unexceptional intervening or autonomous systems. After the evaluation of the driving tests, it will be possible to set up a category system for the assessment of ADAS in terms of their added value for elderly drivers.

3.2 Experimental vehicle

Two Audi A5 were chosen as the experimental vehicles for the tests on active steering and a Volkswagen Passat CC for the tests on Brake Assistant and Brake Assistant Plus. The test drives with the Brake Assistant systems are not finished yet. Thus, no results on Brake Assistant and Brake Assistant Plus will be displayed in this paper. For the test runs with the active steering, one car was equipped with an active steering system, so that it was possible to compare one car with active steering with another car without active steering. For the recording of data in the vehicle the CANalyzer software package was used, which was run by a laptop within the car. All necessary data were available on monitoring-network-CAN and could be read and saved from there.

3.3 Experimental arrangement

All tests took place at the test track of the ika (Institute of Automotive Engineering) of the RWTH Aachen University. The test track consists of an absolutely flat circuit with a diameter of 100 m, which is tangential connected to a 600 m long and 22.5 m wide straight line. The end forms a small turning circle with a diameter of 40 m (Figure 1).
3.4 Acceptance and Workload investigation

The acceptance and workload investigation included a survey of the attitudes of the probands towards the systems/elements of ADAS before the test drive, an observation during the test drive as well as a workload assessment using the NASA-TLX immediately after the individual maneuver that were driven.

To collect data about the attitude of the proband before the test drives, a standardized questionnaire was developed. In addition to demographic data, information on the driving experience and driving habits of the probands and their knowledge of the ADAS to be tested were queried. The questionnaire is intended to create a comprehensive profile of attitudes of the probands, which can be used as an explanatory background for the findings of the final workload assessment.

Following each driving maneuver, the subjective workload of the probands was collected via another questionnaire. For this purpose the standardized NASA Task Load Index (NASA-TLX) was selected. The NASA-TLX quantifies subjective workload using a multidimensional scale (Figure 2). The six defined categories are:

- Mental demands (How much mental and perceptual activity was required (e.g., thinking, deciding, calculation, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?)
- Physical demands (How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?)
- Temporal demands (How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid?)
- Own performance (How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?)
- Effort (How hard did you have to work (mentally and physically) to accomplish your level of performance?)
- Frustration (How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complaced did you feel during the task?)
These dimensions are weighted based on a paired comparison. At first 15 pairs are formed from the six dimensions. The probands then decided which of the dimension was perceived as the more strenuous category. The information how strenuous an activity in each dimension was evaluated, was multiplied by a factor determined by paired comparison (Figure 3). After each driven maneuver the probands had to fill a workload questionnaire in which they evaluated the above categories on a 12-cm-scale. The weighting of the dimensions was carried out at the end of all maneuvers. This way the probands were able to decide which dimensions were more strenuous than others, regarding all completed maneuvers.

Figure 2: Rating scale of NASA-TLX (Hart, Staveland 1988)

Figure 3: Weighting of the different dimensions of NASA-TLX (Hart, Staveland 1988)
3.5 Sequence of the experimental rides
During the tests drives for the investigation of active steering the probands drove a series of three maneuvers on the test track. Different data were recorded, by which the impact of the investigated ADAS were reviewed. All probands were asked before the driving tests about their knowledge about the function of different ADAS and about their attitudes towards the ADAS. After they had driven a maneuver, the probands workload was evaluated via the NASA-TLX questionnaire. To be able to make a statement about the effect of ADAS on elderly drivers, all driving tests were additionally done with a control group consisting of experienced drivers aged 30 to 55 years.

To investigate the active steering three maneuvers were performed. First, the probands had to turn over the vehicle in several moves in a narrow track. Second, they had to drive through a marked out slalom course. The construction of the course forced the drivers to perform different steering movements. And third, the probands had to carry out a µ-split-full-brake-application with the left wheels on a wet rubber mat and the right wheels on asphalt. All maneuvers had to be completed with the car that was equipped with an active steering system and the one that was not. The order in which the cars and the maneuvers where selected was randomized. Only the µ-split-full-brake-maneuver was always driven last. During the test drives the steering angle, speed, acceleration and the angle of yaw were recorded. After each maneuver, the probands were asked to fill out the NASA-TLX workload assessment for the particular maneuver (Figure 4).

Figure 4: Design of the test procedure

4 GENERAL DATA OF PROBANDS OF ACCEPTANCE INVESTIGATION
The experimental group of elder people consisted of 30 people. Seven female probands were in the experimental group and 23 men. The control group consisted of 32 people, five of them being female and 27 being male. The probands in the experimental group were between 64 and 74 years old, while the people in the control group were between 35 and 50 years old. The driven kilometers per year are balanced between the two groups. In both groups there are almost the same number of people who drive more than 15000 kilometers per year and people who drive between 0 and 15000 kilometers per year. 63,3 % of the experimental group and 62,5 % of the control group stated that they drive less than 15000 kilometers per year. These results strongly suggest that there is no huge difference between the experimental and the control group concerning the driven kilometers per year. There is a small difference between experimental and control group concerning probands driving less than 5000 kilometers per year: 20 % of the asked persons in the experimental group dive less than 5000 kilometers per year while only 12,1 % of the persons in the control group do.
Most of probands in both groups use their car nearly every day. 63.0% of the experimental group declared that they use their car daily and 30.0% stated that they use their car every two to three days. 71.9% of the control group use their car on a daily basis and 15.6% drive their car every two to three days. The frequency of using the car seems to be not very different according to both groups.

When being asked for an evaluation of their own driving performance in general, 36.7% of the experimental group think that their own driving performance is good and 59.4% of the control group evaluate their own performance as good. A slight difference can be seen here: the younger drivers seem to be more confident about their own driving performance. 15.6% of the control group strongly agree that they see their self as a very good driver while none of the older probands strongly agree with this. This result is also intensified by the fact, that 16.7% of the experimental group would estimate their own driving performance as rather bad. Only 3.1% of the control group estimate their performance in driving as rather bad (Figure 5).

![Figure 5: Evaluation of the own driving performance in general](image.png)

When being asked which situations in traffic (e.g. turn left and right, overtaking, crossroads, etc.) are risky in their opinion, it turned out that elder people more often agree that situations like turning left, overtaking, etc. are risky than probands of the control group. On the other side, only 53.4% of the experimental group are open-minded about ADAS while 71.9% of the control group are. 16.7% of the experimental group state that they are not open minded about ADAS, while only 3.1% of the control group state this. In both groups, the majority of the probands have a high open mindedness concerning technology in general: 63.3% of the experimental group and 87.6% of the control group state that they are open minded. The difference between the experimental and the control group is also demonstrated by the result of the probands’ open mindedness concerning technology in the car. Although the majority of both groups is open minded about it (experimental group: 53.4%, control group: 87.5%) there still is a difference of nearly 25% between the groups. This demonstrates that although the majority of elder people seem to be open minded concerning technology in
general, technology in the car and ADAS in the car, younger people are still more open minded about these factors (Figure 6).

![Open mindedness concerning the following technologies in %](image)

Figure 6: Open mindedness concerning several technologies

When asked about the functions of specific ADAS, there were no huge differences between the two groups. 76.7% of the experimental group and 75% of the control group think that a system that hints the driver at possible risks is helpful. A system that takes over individual driving tasks when there are dangerous situations is rated as helpful by 60% of the experimental group and 53.2% of the control group. ADAS that take over individual driving tasks to support the driver are perceived as helpful by 50% of the experimental group and 40.7% of the control group. 73.4% of the experimental group and 71.9% of the control group think a ADAS that gives information about certain facts while driving is helpful for the driver. These results show an open mindedness concerning ADAS in the majority of both groups.

6 RESULTS OF THE WORKLOAD INVESTIGATION
As mentioned before, not all test drives were completed yet. Therefore only the analysis of the Active Steering will be described here. As mentioned above, the subjective evaluation of the workload index was carried out by the probands via the NASA-TLX questionnaire after each maneuver they had driven.

The results of this evaluation showed that there is no significant difference between the experimental group, aged older than 65 years, and the control group, aged between 35 and 50 years. The investigation showed that there are only minimal differences in the way the experimental and control group subjectively evaluated the workload indices for themselves for the tasks they were given. The evaluation of the individual workload indices referring to the dimensions Mental Demand, Physical Demand, Temporal Demand, Effort, Own Performance and Frustration Level also showed no significant distinctions in the subjective evaluations of both age groups.

Another result of the test drives was that the maneuvers according to their workload indices were not evaluated differently, regardless of being driven with a car that was equipped with Active Steering or a car that was not equipped with Active Steering. The answers of the
NASA-TLX questionnaire showed that the maneuvers driven with the car equipped with Active Steering did not get better results according to the workload index that was subjectively indicated by the probands. Thus, probands driving the car with Active Steering were not less stressed during the maneuvers than they were during driving the maneuvers with the driver assistance systems turned off.

7 CONCLUSION
In this paper a brief introduction about the project Criteria for age based design of active vehicle safety systems was given. It also described the individual steps of the project. First the requirement analysis and its results were demonstrated. This analysis strongly suggested that elderly people account the car as the most desirable mean of transportation and that cars support elderly people in remaining their mobility. Within the described market analysis specific ADAS systems were chosen for the test drives. As a next step the experimental design and the acceptance and workload investigation were presented.

The acceptance investigation showed that there are some differences in their answers concerning the experimental and the control group. The questionnaire suggested that younger persons are more open minded about technologies in general, technologies in the car and ADAS. The results of the workload investigations showed that there is almost no difference between the stress level of the experimental and the control group. In addition to that no clear difference between the test runs with and without ADAS have been found, The results of the workload investigation indicated that the probands were not relieved by the analysed ADAS when driving the individual maneuvers, but were not additionally stressed by them either. Because the existing data is exclusively based on the probands’ subjective evaluation it is necessary to compare these subjective results with the objective driving data recorded during the test drives. This will be done within the next months and published in the future.

REFERENCES

Contents session 15 Enforcement techniques, traffic laws and self enforcing designs

Effectiveness of a System Automatic Speed Control on National Roads in Poland
Mariusz Kiec, Cracow University of Technology, Poland

Video Cameras as Red Light Running Countermeasure UAE Experience
Dr. Essam Radwan, CATSS, University of Central Florida, USA

Laurent Carnis, INRETS/DEST, France

An Assessment of Road Safety and Accident Policy Transitions and Pathways in Uganda: Milestones and Priorities for Immediate Action
Paul Isolo Mukwaya, Department of Geography Makerere University, Uganda

Assessment of Traffic Monitoring Technologies of Relevance to Traffic Safety in UAE
Faisal Ahmed (RTTSRC) UAE University, Al Ain, United Arab Emirates
ABSTRACT
The article describes general determinants of automatic speed control system implementation on Polish roads. The first stage includes building a network of measurement stations for automatic speed control. Building a network of speed cameras has been accompanied with analysing ‘before and after’ to assess the effectiveness of the applied methods of both: speed reduction and improving safety.

The paper presents analyses of:
• the characteristics of speed problems on Polish roads before speed cameras installation and suggested speed management measures,
• a system for automatic speed control and rules for building a network of measurement stations,
• the effect of speed cameras on speed, changes in accident number and structure as well as public acceptance.

The results of the analyses proved that exceeding speed limits is a characteristic feature of drivers’ behavior on national roads in Poland. The paper includes the data that illustrate allowable speed limit exceeding and it describes the principles concerning building a network of measurement stations for automatic speed control as well. The initial evaluation of results of the speed control implementation indicate the reduction of average speed in speed cameras zones by c 12-16 km/h and accident rate reduction by c 28%.

The results of the analyses lead to the conclusion that speed cameras are measures accepted by the majority of Polish drivers and they seem to be an effective means in traffic safety improvement. Other factors, such as reconstruction of infrastructure, training, police monitoring etc. turn out to be of high importance as well.

1 INTRODUCTION
In order to investigate the high number of accidents occurring on Poland’s national roads, including those caused by excessive speed, speed management measures must be undertaken. Implementation of lower speed limits in 2004 i.e. 50 km/h (instead of 60 km/h) in built-up areas, was not fully accepted by drivers and did not change their behaviour significantly. The average reduction of the mean speed on the analysed roads was between 1,7 and 3,3 km/h. The empirical studies, which the authors have conducted for the National Road Safety Council since 2002, have confirmed drivers violating the speed limits, also in rural areas, which calls for more restrictive speed enforcement measures. However, the recorded speed sample showed a significant spread of speeds exceeding the limit for each group of sections with different types of carriageway.

The paper gives an overview of a system for automatic speed control on Poland’s national roads and the first results of its use. Works on the implementation began in 2007 and have been continued as part of a programme of accident reduction on national roads. In the first phase, i.e. in the period 2007-2008, some 600 speed measurement stations were set up. Speed
cameras are located in high risk sites that have been chosen after in-depth studies of speed and its effects on accidents. Building a network of speed cameras has been accompanied by ‘before and after’ analysis to assess the effectiveness of the applied methods of both speed reduction and safety improvement.

The paper presents analyses of:
- the characteristics of speed problems on Polish roads before speed cameras installation and suggested speed management measures,
- a system for automatic speed control and rules for building a network of measurement stations,
- the effect of speed cameras on speed, changes in accident numbers and structure as well as public acceptance.

2 SPEED AND SAFETY PROBLEMS ON POLISH ROADS

The issue concerning the influence of speed on traffic safety was a subject of numerous research studies (Baruya, Elvik, Vaa, Finch et al., Gaca 2002). The results of most of them confirm the gravity of speed as one of determinants of traffic safety. A comprehensive analysis of accidents on national roads in Poland in recent years has allowed formulation of the following statements (Jamroz et al.):
- high accident severity with as many as 13 fatalities per 100 accidents in built-up areas and 24 deaths outside built-up areas per 100 accidents;
- unusually high number of pedestrian accidents (22%) compared with the actual pedestrian traffic volume. Pedestrians make up on average 29% of total road deaths on national roads, but there are substantial differences from region to region. Cyclists are equally at risk with an average of 6% of all injuries and 9% of all killed, while they only make up some 1% - 2% of traffic;
- a high number of fatalities in head-on collisions at 29% of all fatalities on national roads with head-on collision making up 17% of total accidents;
- accident risk at junctions usually involving side impact accidents at 24% of accidents;
- the presence of roadside lateral obstacles and frequent collisions with these – on average 10% of all accidents, but with regional variations (7.2% - 14.8%);
- speed not appropriate to the conditions being the most frequent cause of driver related accidents. On average in a year 26% of accidents involve speeding and claim 29% of injuries and 26% of all road deaths;
- failure to observe speed limits in non built-up areas and on roads passing through towns.

Taking into account the results of the conducted speed surveys and the analyses of accident data the following tasks, oriented towards solving speeding problems, were included in National Road Safety Program GAMBIT’2000 and GAMBIT’2005:
1. Amendment of legal acts which will facilitate influencing drivers’ behaviour as well as increasing the effectiveness of sanction for speeding offences.
2. Development of education and communication with society in order to promote safe speed driving. The first stage is to heighten the awareness of the dangers of speeding. Informative – promoting campaigns will support the preventive actions as well as controls by different public services. An important aim is to obtain social negative attitude towards ignoring speed limits.
3. Modernisation of speed limit enforcement. This will take place through the improvement of equipment for technical services (the increase of automatic monitoring) and more rational selection of random speed control points. This selection must be oriented towards elimination of drivers’ improper behaviour in the places of increased risk.
4. General verification of speed limits. One of the reasons for low level of acceptance of local speed limits is their low credibility and low variety of use. Therefore, it is essential to re-establish the rules of setting speed limits as well as to use more credible signs of variable content. Another group of tasks constitutes implementation of speed zoning in cities and dissemination of traffic calming solutions.

5. Conducting systematic speed surveys. This means the development of speed monitoring and implementation of periodical assessments of different measures influencing speed. The degree of implementation of the above objectives varies. The most important achievement was changing the speed limit in built-up areas. In May 2004 the speed limit was reduced from 60 km/h to 50 km/h between 5:00 AM and 11:00 PM.

The authors of the paper took part in a speed monitoring program in the period 2002-2008 and studied the influence of speed limit reduction on the drivers’ actual behavior (Gaca et al. 2003, 2007). The studies presented here include the results from over 90 sections of roads passing through small towns (124 daily measurements). The mean values of average speeds $V_A$, $V_{85}$ percentile and percentage of cars exceeding the speed limit $P_V$ on road sections passing through small towns and in cities calculated for a time of the day (5 AM – 11 PM) and during night-time (11 PM - 5 AM) in the period ‘before’ reducing the speed limit were shown in Table 1. The calculations did not cover winter time (only good weather conditions were involved). The values illustrate the essential problem of road safety risks on sections passing through small towns and cities. They confirm the significance of speed reduction both in the time of day and at night-time (with the same speed limit - 60 km/h). It ought to be emphasized that the values of speeds recorded in time intervals were considerably scattered (within road sections of the same type of cross-section). Therefore, the averaged values can be used only for a general characteristic of drivers’ behavior.

Table 1: Average speed parameters on through roads and streets by type of carriageway – day and night for the period ‘before’ limit reduction.

<table>
<thead>
<tr>
<th>Type of carriageway</th>
<th>Speed parameters</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_A$ [km/h]</td>
<td>$V_{85}$ [km/h]</td>
<td>$S$ [km/h]</td>
</tr>
<tr>
<td><strong>through roads</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z1</td>
<td>Day 79.9</td>
<td>94.9</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Night 81.3</td>
<td>96.1</td>
<td>15.1</td>
</tr>
<tr>
<td>Z2</td>
<td>Day 73.1</td>
<td>87.6</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Night 76.3</td>
<td>90.3</td>
<td>14.9</td>
</tr>
<tr>
<td>M3</td>
<td>Day 66.8</td>
<td>79.5</td>
<td>13.6</td>
</tr>
<tr>
<td></td>
<td>Night 71.8</td>
<td>85.1</td>
<td>13.7</td>
</tr>
<tr>
<td><strong>streets in large cities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>Day 64.9</td>
<td>75.8</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>Night 68.2</td>
<td>78.8</td>
<td>12.4</td>
</tr>
<tr>
<td>M2</td>
<td>Day 54.2</td>
<td>65.5</td>
<td>11.6</td>
</tr>
<tr>
<td></td>
<td>Night 60.7</td>
<td>73.1</td>
<td>13.1</td>
</tr>
<tr>
<td>M3</td>
<td>Day 55.5</td>
<td>66.3</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>Night 61.1</td>
<td>75.1</td>
<td>13.4</td>
</tr>
</tbody>
</table>

*) Z1 – single carriageway 7.0 m wide and bit. shoulders, Z2 - single carriageway 7.0 m wide and hard shoulders, M1 – two-carriageway street, M2 - single carriageway 7.0, M3 - single carriageway 8.0 – 9.0 m wide with pavements.
Exceeding speed limits is a characteristic feature of drivers’ behavior also on roads outside built-up areas (Table 2). The values in Table 2 are calculated for vehicle stream data collected on 115 road sections (427 daily measurements) in non built-up areas. The data in brackets present the minimum and maximum daily values in parentheses. The average values are calculated for different seasons. Speed values tend to be higher during seasons with good weather.

In the evaluation of the impact of speed limit reduction from 60 to 50 km/h on built-up areas the results from 40 streets in 16 large cities and from 39 randomly selected sections of roads in small communities and small towns have been used. A comparison of values “before” and “after” has been set up in Table 3. The figures confirm the assumption that drivers’ behavior on speed limit reduction depends on both the type of carriageway and the value of speed “before”. Drivers’ behavior to 3 km/h reduction of average speed is similar to their behavior in other countries where the limit was reduced by 10 km/h. In Poland the recorded speed values still considerably exceed the acceptable limits. It occurs mainly on transit road sections in small towns. Therefore, implementation of additional factors enforcing speed limit obedience and consequently, traffic safety improvement has been considered crucial. One of the factors is automatic speed control.

Table 2: Average daily speed parameters on national roads by type of carriageway.

<table>
<thead>
<tr>
<th>Type of carriageway *)</th>
<th>Speed parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_4$ [km/h]</td>
</tr>
<tr>
<td><strong>Z1</strong></td>
<td>86.2 (80.3 - 100.3)</td>
</tr>
<tr>
<td><strong>Z2</strong></td>
<td>84.7 (80.8 - 90.4)</td>
</tr>
<tr>
<td><strong>Z3</strong></td>
<td><strong>85.1</strong> (79.3 - 93.1)</td>
</tr>
</tbody>
</table>

*) Z1, Z2 – as in Table 1, Z3 - single carriageway < 7.0 m wide and hard shoulders
Table 3: Comparison of values of selected speed parameters in the period ‘before’ and ‘after’ speed limit reduction.

<table>
<thead>
<tr>
<th>Type of carriageway *)</th>
<th>Difference of speed parameters ‘before’ and ‘after’</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_A$ [km/h]</td>
<td>$V_{85}$ [km/h]</td>
</tr>
<tr>
<td>Large cities</td>
<td>Day 5:00 AM– 11:00 PM</td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>-2.22</td>
<td>-2.33</td>
</tr>
<tr>
<td>M2</td>
<td>-0.27</td>
<td>-0.92</td>
</tr>
<tr>
<td>M3</td>
<td>-0.33</td>
<td>-0.50</td>
</tr>
<tr>
<td>Communities and small towns</td>
<td>Day 5:00 AM– 11:00 PM</td>
<td></td>
</tr>
<tr>
<td>Z1</td>
<td>-3.33</td>
<td>-4.55</td>
</tr>
<tr>
<td>Z2</td>
<td>-3.29</td>
<td>-4.79</td>
</tr>
<tr>
<td>M3</td>
<td>-0.94</td>
<td>-1.43</td>
</tr>
<tr>
<td>Large cities</td>
<td>Night 11:00 PM – 5:00 A</td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>-0.55</td>
<td>-0.71</td>
</tr>
<tr>
<td>M2</td>
<td>0.21</td>
<td>0.81</td>
</tr>
<tr>
<td>M3</td>
<td>1.29</td>
<td>1.12</td>
</tr>
<tr>
<td>Communities and small towns</td>
<td>Day 5:00 AM– 11:00 PM</td>
<td></td>
</tr>
<tr>
<td>Z1</td>
<td>0.09</td>
<td>-0.92</td>
</tr>
<tr>
<td>Z2</td>
<td>-1.70</td>
<td>-3.33</td>
</tr>
<tr>
<td>M3</td>
<td>-0.17</td>
<td>-1.34</td>
</tr>
</tbody>
</table>

*) as in Table 1 and Table 2

3 A SYSTEM FOR AUTOMATIC SPEED CONTROL ON NATIONAL ROADS

Based on foreign experience and a diagnosis of accident risks including speed tests, the following criteria have been formulated for selecting speed camera locations and methods of enforcement:

- speed enforcement and control should be ensured on sites where speeding accidents are particularly frequent. Equally important are high risk sites with speed having an indirect effect on the causes of accidents. Before selecting the locations for speed cameras, high accident density sections of roads must be identified where accident rates are significantly above the average;
- once selected, the sections should form a network of measurement points on roads that are interlinked within the region; that way we can increase coverage and improve detection rates;
- while a single speed camera can be moved between several measurement points, speed should be recorded at least once a week for 6 - 24 hours;
- apart from stationary speed cameras, mobile devices should be used for measurements on sites selected at random;
- fixed speed camera sites must be adequately marked and drivers must be able to see the cameras;
- existing local speed limits in or around a speed camera site must be reviewed to ensure that drivers can accept and understand them;
- campaigns to explain the reasons for installing cameras and the expected benefits must be conducted;
high risk sites should be identified by “searching” accident databases for section of 1 km with steps every 100 m. The identification criterion should be related to average accident density or other accident indicators;
- the critical sections should be identified for accidents directly or indirectly caused by excessive speed;
- sections with no speed control must not be too long. This is why the boundary values of indicators for identifying high risk sites should be determined based on average accident risks on the particular sections of the network rather than on the entire road;

Once selected, sections of roads must be verified on site with special focus on:
- road design that encourages high speeds and whether that could be changed;
- errors in road infrastructure that could be a possible cause of accidents;
- the clarity of local speed limits, if there are any, and the possibility to use additional road measures to reduce speed.

The basis of the above findings appointed the localization of speed cameras on general road network. Stage 1 includes localization of 575 measurement stations on the main road network of 4100 km in total (roads No 1 - No 9). Stage 2 determined extension of the network by 275 stations, but the amendment of legal acts brought about the further development of automatic speed control network being taken over by Traffic Authority Inspector. It will take over the speed supervisory duties of the Police. The localization of measurement stations was initiated in 2007. Until mid 2009 about 470 speed cameras were installed. In what follows the analyses of automatic speed limit cameras effectiveness on the selected road sections, particularly on the 735 km national road (No 8) are presented. On this road section the road authority initiated in 2007 a program “confidence on road” aiming at extensive implementation of factors that determine road safety. (www.gddkia.gov.pl).

4 ANALYSES OF EFFECTIVENESS OF SPEED CAMERAS

In order to assess the effectiveness of the network of speed cameras localization basic analyses of „before” and „after” period has been used. In the assessment the following direct measures of speed cameras effectiveness were adopted:
- reduction of accident and collision rate,
- changes in accident structure and their severity.

However, the analysis of the above requires long term studies and is not always possible. Furthermore, reliable data on collision rate on Polish roads are hardly obtainable. Therefore, together with the evaluation of changes of recorded accident rate, the following measures were taken into account:
- reduction value of mean speed and quantiles after speed cameras localization,
- level of speed limit acceptance,
- change of the nature of speed distribution, homogeneity of speed data from one test.

Additionally, the analyses included the social attitude towards speed cameras and drivers’ declared willingness to reduce speed.

The above studies concern the analyses shortly ‘after’ installing the network of speed cameras stations and that is the reason why the assessment of changing safety level ought to be considered as preliminary.

4.1 The effect of speed cameras on speed

The comparisons took into account the following: average speed – $V_A$ [km/h], standard deviation – $S$ [km/h], quantile of speed – $V_{85}$, $V_{95}$ [km/h], percentage of cars exceeding the allowable speed limit – $PV$ [km/h], percentage of cars exceeding the allowable speed limit increased by 20 km/h – $PV_{+20}$ [km/h].
The above were appointed for cars in free flow traffic conditions, where the speed of individual vehicles is not affected by other vehicles and for restricted flow, where the choice of speed is influenced by the speed of other drivers. The data used in the comparisons were taken from the measurements in good weather conditions, for a dry road surface, in the daytime, which eliminated the side factors affecting speed reduction. It also enabled a comparison of the data obtained from different time periods.

The speed analyses conducted to evaluate drivers’ behavior in speed cameras zones included 91 localisations, 50 of which applied to national road No 8. The single measurement included recording the speed ‘before’ and ‘after’ installing a speed camera station. The measurement involved both monitored and not monitored sections. Each measurement station covered 4 measure series – 1 ‘before’ and 3 ‘after’. In total, all series involved the data of speed of nearly 151 000 vehicles ‘before’ and 255 100 ‘after’.

On the basis of the above studies the following parameters have been assessed (Tables 4 and 5). A separate analysis of the data obtained from the studies on national road No. 8 and on other road types results from different means conditioning improving traffic safety on road No. 8. Safety improvement on the remaining part of road sections was conditioned only by speed cameras. Tables 4 and 5 indicate changes in drivers’ behavior on the monitored road sections.

Table 4: Mean values of speed reduction parameters for periods ‘before’ and ‘after’ on national road No. 8.

<table>
<thead>
<tr>
<th>Speed limit [km/h]</th>
<th>Type of traffic</th>
<th>Speed parameters and allowable speed exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$V_A$ $V_{85}$ $V_{95}$ PV $PV_{+20}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[km/h] [km/h] [km/h] [%] [%]</td>
</tr>
<tr>
<td>50</td>
<td>Traffic flow</td>
<td>6.3 6.4 6.1 16.7 13.5</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>4.9 5.8 5.5 6.2 14.6</td>
</tr>
<tr>
<td>70</td>
<td>Traffic flow</td>
<td>6.0 8.6 9.7 7.7 10.4</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>11.5 15.3 16.0 15.9 20.7</td>
</tr>
<tr>
<td>90/100</td>
<td>Traffic flow</td>
<td>8.7 14.9 18.3 23.5 15.2</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>9.9 16.9 18.8 24.9 18.5</td>
</tr>
</tbody>
</table>

Table 5: Mean values of speed reduction parameters for periods ‘before’ and ‘after’ excluding national road No. 8.

<table>
<thead>
<tr>
<th>Speed limit [km/h]</th>
<th>Type of traffic</th>
<th>Speed parameters and allowable speed exceeding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$V_A$ $V_{85}$ $V_{95}$ PV $PV_{+20}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[km/h] [km/h] [km/h] [%] [%]</td>
</tr>
<tr>
<td>50</td>
<td>Traffic flow</td>
<td>12.3 13.9 15.6 25.3 25.9</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>12.9 14.9 17.4 21.0 30.7</td>
</tr>
<tr>
<td>70</td>
<td>Traffic flow</td>
<td>12.6 15.2 18.9 35.1 16.9</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>13.8 18.0 20.8 33.3 15.0</td>
</tr>
<tr>
<td>90/100</td>
<td>Traffic flow</td>
<td>15.6 15.2 18.9 35.1 16.9</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>16.6 12.7 30.3 32.5 15.0</td>
</tr>
</tbody>
</table>

The actual speed reduction on road sections where speed cameras have been installed need to be considered as substantial due to the real traffic safety improvement. However, the values of speed reduction are far smaller than it was expected, since considerable speed limit exceeding was still recorded. In particular, it occurred on 50 km/h speed limit sections with the mean values of $V_A$ and $V_{85}$ for period ‘after’ presented below:
<table>
<thead>
<tr>
<th>Analysed sections</th>
<th>Type of traffic</th>
<th>$V_4$ [km/h]</th>
<th>$V_{85}$ [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>National road No 8</td>
<td>Traffic flow</td>
<td>55.8</td>
<td>66.9</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>58.3</td>
<td>70.0</td>
</tr>
<tr>
<td>Other road sections</td>
<td>Traffic flow</td>
<td>54.7</td>
<td>65.3</td>
</tr>
<tr>
<td></td>
<td>Free flow</td>
<td>56.2</td>
<td>67.7</td>
</tr>
</tbody>
</table>

The above analysis proves the assumption that the effectiveness of speed cameras is far higher on road sections with 70 km/h speed limit than 50 km/h. This fact may result from the customary practice of recording speed limits exceeding on built-up areas with the tolerance of 20 km/h. Also, the current practice of randomly controlled speeds with the use of automatic speed cameras, occurring with low frequency (once/twice a month) appeared to be low-effective. Increasing the frequency of speed recording and substantial reduction of ‘the margin of tolerance’ seem to be indispensable.

Apart from analysing the influence of speed limits in zones with speed cameras on drivers’ behavior other factors determining drivers’ reaction were considered: type of cross-section and density of road development on sections with wide bit.-shoulders. The studies included road sections with 50 and 70 km/h speed limit. The results indicate a significant influence of both the type of cross-section and density of road development on speed of the vehicles in speed cameras zones. The recorded values of speed in dense road development areas were close to the expected ones.

### 4.2 Evaluation of the effect of speed cameras on traffic safety

The assessment of the effect of speed cameras on traffic safety included the evaluation of the so-called ‘network effect’ (change of drivers’ behavior on monitored road sections) and ‘local effect’ (change of drivers’ behavior on short sections ‘in front of’ and ‘behind’ the speed cameras). The analysis involved national road No. 8 where in a short period of time 101 measurement stations were installed (on average, every 7.3 km one station for a speed camera). To evaluate the ‘network effect’ two methods have been applied: comparison of accident rates in successive years and a method of comparison of speed values ‘before’ and ‘after’ speed cameras installation. Taking into account the random fluctuations of accident rates, the changes of accidents recorded in 2008 have been compared to averaged values from the period of 3 years (2004-2006). The values from the period of 2007 have been excluded because at that time long term works on the traffic safety improvement were being carried out. Besides, drivers were supposed to need at least two weeks’ time to get accustomed to new traffic conditions, including intensive speed monitoring.

The comparisons covered the accident rates recorded on road No. 8 and the rates from other national road sections. The other road sections were treated as ‘a subject of control studies’. As a consequence, to some extent, the effect of speed cameras has been separated from general changes of factors determining traffic safety on the whole road network. Such changes occur as a result of parallel works carried out on traffic safety improvement, i.e. redevelopment of infrastructure, changes in traffic organisation, education etc.

Table 6 presents the data concerning the changes of both accident rates and the number of casualties in 2008 related to averaged values from the period of 2004-2006. The data include all types of accidents and accidents caused by potential excessive speed, and they confirm considerably lower rate of accidents on road No 8 in comparison with the other national roads. Yet, this conclusion does not refer to the number of fatalities in accidents caused by speeding.
Table 6: Changes of accident rates and number of casualties in 2008 related to average values from the period of 2004-2006 on national road No. 8 and on the other national roads.

<table>
<thead>
<tr>
<th></th>
<th>Fatalities</th>
<th>Slight and severe injuries</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All accidents</td>
<td>Speeding accidents</td>
<td>All accidents</td>
</tr>
<tr>
<td>Road No 8</td>
<td>-18.2%</td>
<td>-16.5%</td>
<td>-13.4%</td>
</tr>
<tr>
<td>Other national roads</td>
<td>-4.9%</td>
<td>-30.9%</td>
<td>-4.6%</td>
</tr>
<tr>
<td>Difference</td>
<td>-13.3%</td>
<td>+14.4%</td>
<td>-8.8%</td>
</tr>
</tbody>
</table>

The accident rate and number of casualties in the selected speed cameras zones have been evaluated separately - 500 m ‘in front of’ and 500 m ‘behind’ the speed camera station. The recorded changes have been compared with the general trend of accident rate reduction on other roads. The comparison involved two groups of speed monitoring stations. Group A, surveying all speed monitoring stations, and group B considering only stations on dangerous sections. Table 7 presents the results of comparison of ‘before’ (3 years) and ‘after’ (1,5 year) period of speed cameras installation.

Table 7: Changes of accident rates and number of casualties in speed cameras zones on national road No.8 recorded ‘before’ and ‘after’ cameras installation.

<table>
<thead>
<tr>
<th></th>
<th>Fatalities</th>
<th>Slight and severe injuries</th>
<th>Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
<td>Group B</td>
<td>Group A</td>
</tr>
<tr>
<td>Speed camera zones</td>
<td>-41.5%</td>
<td>-41.3%</td>
<td>-33.5%</td>
</tr>
<tr>
<td>Other national roads</td>
<td>-4.9%</td>
<td>-4.6%</td>
<td>-4.6%</td>
</tr>
<tr>
<td>Difference</td>
<td>-36.6%</td>
<td>-36.4%</td>
<td>-28.9%</td>
</tr>
</tbody>
</table>

The data in Table 7 indicate an efficient role of speed cameras in traffic safety improvement. Their presence has reduced the number of fatalities by over 36%, the injured by ca. 29% and the accident rate by ca. 28%.

Distinguishing the two groups of speed cameras localization did not influence the qualitative change of speed cameras efficiency assessment.

An additional analysis of the effect of speed cameras on traffic safety within zones of their operation included a comparison of the pattern of accident types and accompanying circumstances ‘before’ and ‘after’ speed cameras installation. Speed cameras were expected to reduce both accident rate resulting from speeding and caused by any direct or indirect speed related factors. However, the results of statistics studies did not confirm the assumption (statistics significance adopted at 0.1 level). Yet, it needs to be emphasized that the rate of accident circumstances defined as speed not adjusted to traffic conditions decreased from 32.5% in the ‘before’ to 27.95% in ‘after’ period.

The conclusions may hold an error resulting from the relatively short period of data collecting (1.5 year ‘after’ speed cameras installation). This indicates a need for further research.

4.3 Drivers’ assessment of speed cameras

An analysis of drivers’ response to speed cameras has been done to evaluate the degree of their acceptance (within zones of cameras’ operation). The studies involved a comparison of
road No.8 sections with high density of speed monitoring stations and other sections with lower density of their presence. In total, 457 drivers have been interviewed.

The survey included the following questions:

- **Have you ever been fined for speeding?**

  Nearly 68% of the respondents turned out to have been fined for speeding, and 42% have been recorded by speed cameras.

  **Does the awareness of the potential fine motivate you to follow the traffic regulations?**

  Only 71% of the respondents claim the unavoidability of potential punishment motivates them to follow the traffic regulations. It means speed cameras may not be a preventive measure for nearly 1/3 of drivers,

- **What is your reaction to ‘speed camera’ road sign?**

  The respondents declared both a ‘speed cameras’ road sign and a visible speed monitoring station to be influencing their speed reduction, 78% and 79%, respectively, answered YES.

- **What is your reaction to a road mast possibly holding a speed camera?**

  Nearly 59% of the drivers admitted to speed reduction only in front of a speed camera station,

- **Do you think speed cameras are an effective measure of safety improvement on Polish roads?**

  Nearly 76% of the respondents claimed speed cameras to be effective in traffic safety improvement, indicating other measures e.g., road reconstruction, raising road standards, better signing system, improvement of drivers training, increasing drivers’ awareness of road risks, more intensive speed monitoring and police preventive actions.

  Other questions the survey included concerned speed cameras appearance, functioning and their recognizability.

  The results of the survey lead to variety of answers, depending on place of the investigation (road No.8 and other roads), they indicate various levels of intensity of speed monitoring and various attitudes of drivers towards risk resulting from speeding.

  The results lead to the conclusion that speed cameras are measures accepted by the majority of Polish drivers and they seem to be an effective means in traffic safety improvement. Other factors, such as reconstruction of infrastructure, training, police monitoring etc. turn out to be of high importance as well.

5 **CONCLUSIONS**

The results of surveys, speed and speed cameras effectiveness analyses allow to formulate the following final conclusions:

a) low efficiency of speed limits reduction on built-up areas (from 60 km/h to 50 km/h) and low level of respecting other limits resulted in introducing more restrictive measures of speed monitoring on Polish roads. Automatic recording of speeding appears to be one of them,

b) introducing speed cameras resulted in speed reduction within zones of their operation, but the actual reduction appeared to be smaller than it had been. The real speed values turned out to be higher than the speed limits,

c) range of speed reduction on road sections with speed cameras depends on speed limit, type of cross-section and road development density,

d) disadvantageous effect on inadequate changes (recorded in speed camera zones) in drivers’ behavior is exerted by both the practice of using too wide margins of tolerance while recording speeding and monitoring of insufficient frequency. Therefore, organizational changes of automatic speed monitoring have been considered of high importance. A higher intensity of speed control and introducing mobile monitoring, also on road sections out of speed camera zones, have been recommended,
e) in spite of modest effects concerning speed reduction values, the number of fatalities and the injured in road accidents decreased considerably. However, maintaining this effect requires more intensive use of already installed speed camera stations,
f) respondent drivers’ assessment expresses their positive attitude towards speed cameras as a measure of traffic safety improvement. Therefore, social attitude should not be perceived as an obstacle in further speed cameras network development. Additional analyses confirmed the correctness of the applied criteria of appointing new road sections for automatic speed monitoring. Special speed control should be focused on road sections where high accident rate results from speeding.

REFERENCES
ABSTRACT
Red light running is a concerning traffic problem in large cities and urban areas. This paper presents the red light running camera system implementation in Abu Dhabi, exploring experience of the similar systems implemented in other cities around the world and in the United States of America. The paper then introduces information about the characteristics of the intersections where the cameras were installed and documents analysis of a sample of the camera system output. Preliminary results explain red light running trends and discuss the phenomena of concentration of the red light running during the PM peak. The paper concludes that the data provided by the system is comprehensive and can be used to further study the phenomena of red light running.

1. INTRODUCTION
Red light running contributes to substantial numbers of motor vehicle crashes and injuries annually in the United States of America and around the world. Retting et al (2002) reported that drivers who ran red light were involved in an estimated 260,000 crashes
each year, of which approximately 750 are fatal, and the number of fatal motor vehicle crashes at traffic signals increased 18% between 1992 and 1998, far outpacing the 5% rise in all other fatal crashes. The Federal Highway Administration posted the following traffic facts about red light running on their main website:

- Each year, more than 1.8 million intersection crashes occur.
- In 2000, there were 106,000 red light running crashes that resulted in 89,000 injuries and 1,036 deaths.
- Overall, 55.8% of Americans admit to running red lights.
- More than 95% of drivers fear they will get hit by a red light runner when they enter an intersection.

In 2005 alone 96 people were killed and 6,300 were injured in the state of Florida by motorists who ignored traffic signals (cause of the crash would be “failed to follow the traffic light”). For the same year, nationally in the US red light running caused more than 800 fatality and 165,000 injuries.

Red light running is not only a highly dangerous driving act but also it is the most frequent type of Police reported urban crash. A study provided 5,112 observations of drivers entering six traffic controlled intersections in three cities. Overall, 35.2% of the observed signal cycles had at least one red light runner prior to the change phase this rate represented approximately 10 violations per observation hour (Bryan et al., 2001).

2. RED LIGHT RUNNING CAMERAS
Red light running cameras system is considered the most effective red light running counter measure. On the other hand red light running cameras raises privacy and legitimacy concerns by the general public.

Nicholas J. Garber et al., (2007) indicated that the red light running camera enforcement system have many labels like; photo red enforcement, automated enforcement or several other terminologies. such system mainly consists of one more camera that detects the vehicle running the red light and then takes a photograph of the license plate of violating vehicles that enter the intersection after the signal turns red. Usually the system starts after a given fraction of a second called the “grace period”. The system also record some other information about the violation like time of the violation, date of the violation, speed of the violating vehicle, license plates, and the time elapsed after the onset of the red signal. All this information is recorded along with the photo of the violating vehicle. The data will then be reviewed and validated hence the approved violation sent to the vehicle registered owner.

Some other systems promotes the responsibility of the driver, in such case a camera must face the front side of the vehicle to prove the identity of the driver. In such case the ticket issued by the system is equal to the ticket issued by a police officer on site including fine value, point, license suspension etc.

3. SYSTEM EFFECTIVENESS (IMPLEMENTATION EXPERIENCE)
The red light camera enforcement system has been implemented in some communities in the United States of America like Virginia, Maine, Georgia, Arizona, and Iowa. Also many countries have been using the system as possible counter measure for the red light
running problem. In the following section we will summarize some of the locations that implemented the system and their findings.

In 1995 Virginia’s General Assembly authorized the use of photo-red light monitoring as demonstration program in 10 jurisdictions in the commonwealth. The program was implemented in 7 jurisdictions from the year 1997 through 2003. Virginia Traffic Research Center prepared several reports on the program and found that often the rear-end crashes increased and in general the number of crashes at the monitored intersections increased also at some intersections the number of injury crashes increased as well (Nicholas J. Garber et al 2007).

In Georgia the system was authorized to be used in 2003 and in a study conducted by the Red Light Camera Subcommittee of the Georgia section ITE Safety Committee, although reporting the sample size of the study is not statistically significant, the study found that the rear-end crashes increased in general with the exception of one location and the other aspects of safety varied from one location to another. The study showed that the system achieved effectiveness in some locations while nearly did not have any effect in other locations (Scott Younker et al, 2008).

In Iowa the system was first implemented in 2004 and since then three communities have implemented their systems. In a study by Center of Transportation Research and Education “Iowa state university” it was found that the camera system is highly effective in reducing red light running related crashes and also it succeeded in reducing the rear end crashes at the monitored intersections. The study found that the monitored intersections observed 40% reduction in overall crashes while intersections that did not have the system observed only 12% crash reduction. Also the intersection with red light cameras had 90% reduction in red light running related crashes while the other intersections did not have any reduction. The study found that the monitoring system is effective also in reducing the rear –end crashes as intersections with the system observed 40% reduction in rear-end crashes while the control intersections suffered a 29% increase in the rear end-crashes. This is however the first study to report the reduction in rear end crashes as a measure of effectiveness for the red light camera system (Eric J. Fitzsimmons et al 2007).

Also in Arizona a study was conducted to evaluate the effectiveness of the red light camera system. The study found that the intersection with red light cameras had a decrease in the angle crashes resulting from red light running and increase in the rear end crashes. But the study also stated that there is many confounding factors related to safety issue and the red light trend at intersections with no red light monitoring cameras might observe reduction in number of crashes related to red light because of what is known as the of the spillover effect. Also the study suggested that the effect of the red light cameras should be evaluated as a system of intersections performance rather than an intersection by intersection. (Kangwon Shin and Simon Washington, 2007)

A study conducted in Australia compared five years before the red light camera system was implemented and five years after the system implementation. The study did not find any overall reduction in the number of crashes resulting from the system. Low crash sites suffered increase in the crash rate and high crash sites experienced decrease in the number of crashes. Also there was significant increase in the rear end crashes (Andreasssen, 1995).
Although red light running cameras is considered the leading countermeasure used to reduce red light running, there is some opposition to the system implantation in some cities. Elmitiny and Radwan in 2008 examined public prospective of the red light running cameras and how motorists usually perceive the cameras as a revenue generating tool rather than a safety tool aiming to save lives. In their work they explored many cases in which the public fought the camera installation and in some cases through public officials the system was stopped after a test period. They suggested analysis of the cameras output to determine when and where the system will be most effective and at the same time avoid the negative perception of the public as just a tool to generate revenue. (Elmitiny, N., and Radwan, E., 2008)

Most of the studies agreed that the red light cameras increased the rear end crashes (except Iowa State). And while some of them reported effectiveness in reducing red light related crashes some other studies reported very little or no improvement. It is to be noted that some States treat the citation differently by holding the driver responsible for the violation rather than the vehicle registered owner enabling legal treatment of camera citation as if a police officer issued an on site citation. Most of the other red light camera systems send the citation to the vehicle registered owner regardless of who was driving the car at the moment, usually because of this reason caps have to be put on the fines limit and sometimes no points counted and no insurance reporting.

4. ABU DHABI RED LIGHT VIOLATION SYSTEM

Over the last few years, Abu Dhabi City and its environs have experienced tremendous growth in all aspects of urban life. The booming economy has led to increase in population, rising ownership of cars and trucks, and traffic growth. The population in the Abu Dhabi Emirates has grown from 200,000 (1975) to over 3,000,000 (2009). The city and surrounding region has a total population of 1,000,000. The urban structure of Abu-Dhabi Island is laid in a grid network of major high-capacity urban arterial. The road network in Abu Dhabi is a modern, rectilinear system. Major arterial streets typically have dual 3-lanes carriageways. The CBD area consists of multi stories high-rise buildings. Abu Dhabi authorities have focused in the last 20 years in lunching infrastructure projects to cop up with the region growth. Such projects upgraded the road network from a simple network to more comprehensive one. Figure 1 shows the road network in Abu Dhabi island. Also, the region growth resulted in building many new towns around Abu Dhabi city. Such changes converted the trip matrix from a simple O/D matrix to a more complicated one. The changes in the travel patterns create many operational challenges. Such challenges stimulate concerned authorities to direct their attention toward traffic operational problems that facing the city. As it is well known usually traffic operational problems are accompanied with some unacceptable drivers behaviors. One of that behaviors is red light violation and red light running caused crashes. This lead the Abu Dhabi Municipality and Abu Dhabi Traffic police to start putting in place and operating a red light running or red light crossing detection camera system as a red light running countermeasure to reduce the risk of a red light running caused crash. All the intersections covered are in the urban area, all the intersections the intersections where cameras were installed have four legs, 90° angel with all 3 lanes approaches for through traffic, one exclusive left turn lane and one exclusive right turn lane. Signal type in all intersections is fixed time (pre defined plan based on time of day) also all signals are synchronized. Cycle at each intersection of the signal consists of: green phase, flashing green, followed by yellow, then all red and the
red phase. Signal timing is 2 sec flashing green at the end of the green, 3 sec. yellow interval, 1 sec. all red. Posted speed limit is 60kph. Also the intersections reach over capacity state during peak hours. In Abu Dhabi area the peak hours are as follows:

- AM peak 7:00am - 9:00am
- PM peak 1:00pm - 4:00pm
- Evening peak 7:00pm -9:00pm

As indicated in Table 1 Traffic violation recording (TVR) cameras have been installed through out 90 locations that cover 40 intersections. The system transmits images of violating vehicles to a central processing server at the Traffic Control Center (TCC) for verification of offense and identification of offending vehicle and, subsequently, citing the offending vehicle by the concerned agencies. The camera assembly is connected to the intersection traffic signal controller in such a way that it photographs the offending vehicle as the relevant red phase starts, under consideration of a user-defined preset delay time, and switch off automatically at the end of the red phase. The red light violation monitoring system is capable of producing high quality digital color images without any digital image enhancement over a minimum of two (2) traffic lanes in any direction.

The system is designed to capture three different pictures. The first picture captured by the DC shows the offending vehicle seen in its direction of movement, with its front axle positioned approximately in the centre of the loop. At the same time a second picture photographs the whole scene of the intersection with the offending vehicle and the active
red light clearly shown in the picture. The third picture is usually taken after a user-selected interval time has elapsed.

<table>
<thead>
<tr>
<th>IP No</th>
<th>Intersecting Road Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>1E</td>
<td>Airport Road Al Manhal Street</td>
</tr>
<tr>
<td>4</td>
<td>King Khalid Bin Abdul Aziz Street Zayed the First Street</td>
</tr>
<tr>
<td>5A</td>
<td>Zayed The First Street Al Khaleej Al Arabi Street</td>
</tr>
<tr>
<td>6</td>
<td>Sultan Bin Zayed The First Street Zayed The First Street</td>
</tr>
<tr>
<td>7A</td>
<td>Corniche Road Al Khaleej Al Arabi Street</td>
</tr>
<tr>
<td>9</td>
<td>Salaam Street Hamdan Street</td>
</tr>
<tr>
<td>10</td>
<td>Hamdan Street Baniyas Street</td>
</tr>
<tr>
<td>14</td>
<td>Khalifa Street East road extension</td>
</tr>
<tr>
<td>118</td>
<td>Baynoonah Street 19th Street</td>
</tr>
<tr>
<td>17</td>
<td>Hamdan Street Baniyas Street</td>
</tr>
<tr>
<td>24A</td>
<td>King Khalid Bin Abdul Aziz Street Zayed The First Street</td>
</tr>
<tr>
<td>28A</td>
<td>Airport Road 27th Street</td>
</tr>
<tr>
<td>28B</td>
<td>24th Street 27th Street</td>
</tr>
<tr>
<td>35</td>
<td>Baniyas Street Al Falah Street</td>
</tr>
<tr>
<td>36</td>
<td>Salaam Street Al Falah Street</td>
</tr>
<tr>
<td>38</td>
<td>Zayed the Second Street 10th Street</td>
</tr>
<tr>
<td>40</td>
<td>Airport Road 11th Street</td>
</tr>
<tr>
<td>41</td>
<td>10th Street Meena Road</td>
</tr>
<tr>
<td>42P</td>
<td>Al Karamah Street Al Sudan Street</td>
</tr>
<tr>
<td>43</td>
<td>Airport Road Hazza Bin Zayed Street</td>
</tr>
<tr>
<td>43A</td>
<td>Hazza Bin Zayed Street East road extension</td>
</tr>
<tr>
<td>44A</td>
<td>Baniyas Street Hazza Bin Zayed Street</td>
</tr>
<tr>
<td>49A</td>
<td>East road extension Mohammed Bin Khalifa Street</td>
</tr>
<tr>
<td>49</td>
<td>Airport Road Mohammed Bin Khalifa Street</td>
</tr>
<tr>
<td>57Q</td>
<td>Al Sudan Street Al Khaleej Al Arabi Street</td>
</tr>
<tr>
<td>59</td>
<td>Mohammed Bin Khalifa Street Khaleej Al Arabi Street</td>
</tr>
<tr>
<td>63A</td>
<td>Cross Road Breakwater Street</td>
</tr>
<tr>
<td>70</td>
<td>East road extension Al Saada Street</td>
</tr>
<tr>
<td>75A</td>
<td>East road 29th Street</td>
</tr>
<tr>
<td>76</td>
<td>Airport Road 29th Street</td>
</tr>
<tr>
<td>86</td>
<td>East Road Extension 21st Street</td>
</tr>
<tr>
<td>111</td>
<td>Eastern Ring Road 31st Street</td>
</tr>
<tr>
<td>135</td>
<td>Khaleej Al Arabi Street Saeed Bin Tahnoon Street</td>
</tr>
</tbody>
</table>

5. DESCRIPTION OF CAMERA OUTPUT DATA
The Camera system output is a comprehensive data file reporting extensive data about the red light running incident and the vehicle in violation. Example shown in Table the camera records the data and time of the violation and along with the vehicle registration information it also records the type of the vehicle (passenger vehicle, Heavy truck, trailer…. etc). This comprehensive output allows the analysis of red light running trends
as well as monitoring the overall effectiveness of the system in reducing the red light running rates over time.

### Table 2: Red light running camera output Example

<table>
<thead>
<tr>
<th>NO.</th>
<th>Date</th>
<th>Time</th>
<th>Red Time Elapsed (sec.)</th>
<th>* Plate No.</th>
<th>Plate Type</th>
<th>Plate Origin</th>
<th>Veh. Type</th>
<th>Camera No.</th>
<th>Photo Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>6314</td>
<td>25082009</td>
<td>130214</td>
<td>1.12</td>
<td>XX</td>
<td>51</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036314_4_100 0001_001B</td>
</tr>
<tr>
<td>6315</td>
<td>3092009</td>
<td>133237</td>
<td>1.4</td>
<td>XX</td>
<td>51</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036315_2_100 0001_003B</td>
</tr>
<tr>
<td>6316</td>
<td>3092009</td>
<td>174235</td>
<td>1.62</td>
<td>XX</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036316_0_100 0001_005B</td>
</tr>
<tr>
<td>6317</td>
<td>26082009</td>
<td>131605</td>
<td>3.10</td>
<td>XX</td>
<td>50</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036317_9_100 0001_008B</td>
</tr>
<tr>
<td>6318</td>
<td>6092009</td>
<td>14231</td>
<td>23.25</td>
<td>XX</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036318_7_100 0001_012B</td>
</tr>
<tr>
<td>6319</td>
<td>8092009</td>
<td>33404</td>
<td>1.57</td>
<td>XX</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>87</td>
<td>001_036319_5_100 0001_023B</td>
</tr>
</tbody>
</table>

*Plate numbers were removed for privacy

6. PRELIMINARY DATA ANALYSIS

Examining the red light running incidents that occurred during the months of August and September of 2009 the following observations can be drawn.

- The data analyzed contained 147 red light running incidents distributed over different intersections and approaches.
- As shown in Figure 2 out of the 147 red light running incidents, 21 incidents have taken place during AM peak (7:00am - 9:00am), 79 occurred during PM peak (1:00pm - 4:00pm) while 18 occurred during Evening peak (7:00pm - 9:00pm).
- 57.1% of the total red light running violations occurred during peak hours While 42.9% occurs during the off peak hours as shown in Figure 3.
- Examining Figure 3 it can be observed that the AM peak accounts for 11.0% of the violations, the PM peak accounts for 37.6% and the evening peak accounts for 8.6% of the total violations of the day.
Examine the red light running trend over the day we observe a red light running peak at the start of the PM peak time during 1:00 pm. After the PM peak the red light running starts to decline until the beginning of the evening peak at 7:00 PM then continue climbing till it reaches another peak at 11:00 pm. As shown in Figure 4.
7. CONCLUSION

Red light running cameras is the leading countermeasure to reduce red light running rates. The system is applied in many cities and urban areas around the world with different rates of success depending on the public acceptance of the system. The characteristics of the red light running trends in the city of Abu Dhabi reveal that the majority of red light running occurs during the traffic peak hours of the day (AM, PM, and EV). The traffic peak hours in Abu Dhabi only accounts for 55% percent of the total hours of the day while in a typical traffic network peak hours are extended over more number of hours. Drivers usually have more cautions while driving during peak hours and they travel with much lower speed compared with off peak conditions (this implies that the more dangerous red light running occurs during the off peak times of the day). Also, they always try not to commit red light running violation however because they are usually stressed with traffic congestion it was found that the majority of violation take place during peak hours.

Future work will include more data collection to explore possible correlation between red light violations and traffic conditions, area characteristics, vehicle type, and other relevant variables.

REFERENCES


Federal Highway Administration (FHWA), (2003) Website:  


Abstract:

Speeding has been identified as an important factor in road accidents and as one of the "fatal four" requiring the implementation of a public policy from the appropriate authorities. Different tools are available to governments’ intent on making drivers observe the Highway Code: educative measures, communication campaigns and rehabilitation programmes can be put into effect, whereas speed checking devices can help with enforcement of speed limits and punishment of offenders. The ultimate goal is to reduce the number of fatalities and injuries on the roads.

Many changes have taken place in France since 2000 and impressive results have been obtained during the last decade, with road fatalities down by 40% since 2002. Thousands of deaths and injuries have been avoided. The outstanding factor here is the implementation of an automated speed enforcement programme (ASEP). However other important changes have also taken place and 2000–2009 has been a decade of real evolution for speed enforcement policy in France.

This contribution proposes to investigate the nature of the changes which occurred during the last decade with regard to speed enforcement: new legislation, political commitment and the implementation of an ASEP. The second section investigates the modalities of this change in speed enforcement activities: modification of organisation of speed enforcement, evolution of speed offences and the implications for manual speed checks. The last section is concerned with the consequences of these changes: evolution of driving speeds and speeding behaviour.
Introduction

Over the last ten years the road safety situation has undergone a remarkable change in France, with the number of deaths down by over 40% between 2000 and 2008. The injury rate has shown a similar decline. At the press conference organised by the ONISR (National Interdepartmental Road Safety Observatory) to present road safety results for 2008,¹ it was stated that 12,000 lives had been saved and 120,000 injury cases avoided.

What explains such impressive results in just a few years? The introduction of an automated speed enforcement programme (ASEP) has doubtless played a considerable part in reducing road hazards in France, but other measures – the campaigns against driving under the influence of alcohol and drugs, together with educational and training strategies – must also be taken into account. It must be said, however, that the coercive aspect of public road safety policy has been particularly stressed by the authorities in recent years.

This paper offers a study of speeding deterrence policy for the period 2000–2009. Its aim is to achieve a degree of analytical objectivity and to situate recent changes in a broader time frame. The first section argues for the idea that this decade is characterised by a coercive activism that has found expression in the development of new tools and the framing of new laws, with energetic backing from politicians. The flagship measure here remains the automated speed enforcement programme. The second section highlights the consequences of this public-sector policy on violation behaviours. Modes of checking and sanctioning have changed, with automation now playing a major role. The rise in the use of automatic devices has in turn brought a steep rise in the number of infractions recorded, but manual checking remains a significant means of detection. The third and final section takes a detailed look at speeding behaviour and speed limit violations: here the salient points are lower traffic speeds and greater compliance with speed limits.

1 Organisational and political changes

Organisational changes to do with the policy of deterring excess speed reflect a coercive activism which has led to tougher penalties, the establishment of new infractions and the use of new tools. These new emphases hark back to a political choice made in the late 1990s but put into action only with the introduction of automatic speed detection devices.

1.1. Towards a new coercive activism: the evolution of the legal and operational framework

The decade 2000–09 has been characterised by a marked coercive activism, with the authorities radically modifying the legal framework so as to allow the penalising of new behaviours and more stringent sanctioning of infractions. This has involved changing the operational framework by providing the police with special new equipment. Implementation of this policy was facilitated by at least two factors: firstly, a halt had to be called to the impunity enjoyed by offenders and those responsible for road accidents, this impunity having become less and less tolerable for the general public. Secondly, reinforcement of road safety measures benefited from the favourable context created by the rise of safety issues generally – a context some commentators have openly criticised as "safety psychosis" (Mucchielli 2008).

Changes to the operational framework consist in reinforcing traffic controls via repetition, but also in creating new planning tools for checks. Thus a circular of 20 January 2000 outlined the planning of traffic controls in France's départements, with specific emphasis on achieving consistency at local level by bringing together the various representatives of the forces of law and order and optimising the means of enforcement in the light of the aims being pursued. This involved providing the police with equipment that was new, more sophisticated and better suited to the task in hand. It was planned, for example, that from 2001, the police should receive fifty new radar speed trap devices per month, these being more readily usable than the traditional ones housed in ageing cars. The authorities' aim was a 10% increase in checks made possible by a 25% increase in finance in the context of a three-year scheme (ONISR 2000, p. 14). Furthermore, the Pélissier Report offered legal solutions, notably that of "owner onus" – responsibility of the vehicle's owner for speed limit violations – and the extension of flat rate fines to all such violations. Implementation of the automated speed enforcement system benefited from these legal and organisational innovations, while fitting with the move towards more effective checking via provision of efficient apparatus.

Another major change came in the form of modifications to the legal framework aimed at penalising new behaviours and imposing heavier penalties. This is not the place for an exhaustive detailing of the different measures, but it is worth noting that a 1998 decree established a "5th category" infraction covering speed limit excesses of 50 kph and more; that the road safety legislation of 18 June 1999 included, among other things, the notion of second or repeated offences for marked violations of the speed limit and the financial responsibility of the owner in cases where the driver could not be identified; and that Law no. 2001–1062 of 15 November 2001 established mandatory, immediate withdrawal of a driver's licence for speed limit excesses of 40 kph and more. In addition, the permis blanc ("discretionary

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www2.securiteroutiere.gouv.fr/cnsr/2-documentsliespagetravaux/01_de_nouveaux_modes.pdf
licence") was abolished.\(^5\) In the course of 2003 various decrees upped the sanctions for failure to wear a seat belt or safety helmet and for driving with a blood-alcohol level of 0.5–0.8 grams. The law of 12 June 2003 offers a clear illustration of the new coercive activism in its extension of penalties (five new offences created) and definition of new violations such as telephone use at the wheel and driving under the influence of drugs. The decree of 6 December 2004 increased the penalty for speed limit excesses of 50 kph and more, while lowering the fine for violations of 20 kph and less. In the same year the maximum blood-alcohol level was reduced to 0.2 grams. The mounting attack on speed violations was continued in 2006, with still higher penalties for infractions of 50 kph and more, plus on-the-spot confiscation of the vehicle.

### 1.2. Commitment by politicians: varying degrees of success

In addition to a coercive activism marked by laws providing for severe speeding sanctions, the Jospin government's minister of transport Jean-Claude Gayssot left his stamp on road safety policy via a number of major decisions. Firstly, road safety was made a major national cause in the course of 2000, mobilising actors from different camps and triggering media interest that would generate a new public awareness regarding the issues involved in road accidents (ONISR 2001, p. 22). In the same year the authorities decided to create a National Council for Road Safety (CNSR), whose mandate was to make submissions to the government and to commission studies and assessments relating to road safety policy.

Nonetheless, the road toll remained on the whole stable for the years 1997–2001, especially in terms of deaths: thus the assertive policy of the period seemed not to have achieved any notable results. Indeed, transport minister Gayssot's declaration that the number of road deaths would be reduced by 50% in 1997–2001 sounded more like an avowal both of the failure of the policy of the time and of the government's inability to induce citizens to change their driving behaviour. 2001, in fact, saw the road safety situation deteriorate.

However, an initial shift was brought about in the course of 2001 in the context of debate about the effects of the presidential amnesty on the road toll. The various presidential candidates were prevailed upon to make their stances and projects clear.\(^6\) Independently of the scientific uncertainties surrounding this kind of effect, the most significant outcome of the debate was to turn road safety into a political issue, and one that president Jacques Chirac would later make skilful use of. A further result was the law of 2002 which set strict limits to road safety violations open to presidential amnesty.

In his presidential address of 14 July 2002, Jacques Chirac announced that road safety would be a priority for his term of office. He called for action signalling "a clean break" with past practice,\(^7\) denounced the "national road safety scandal" and referred to the "barbarous behaviour of some drivers".\(^8\) This top-level commitment by the state would facilitate the gradual introduction of the automated speed enforcement system. Under Prime Minister Jean-Pierre Raffarin the government endorsed the head of state's choices regarding the "war on road hazards", which were described as a "national scourge". The president's engagement with the issue would also facilitate the passing of successive laws instituting, among other things, harsher penalties. The police now felt they had political support in their grassroots combat

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\(^5\) A licence allowing an offender to drive for strictly professional purposes.


against the road toll and so showed increased motivation in carrying out their tasks (Carnis 2008a, p. 227). Generous provision of sophisticated equipment – fast cars, automatic and laser speed detection devices – confirmed presidential and governmental determination to change road safety policy (Carnis 2008b). The president's involvement became even more marked when good results were very quickly achieved: the number of road deaths fell by 25% between 2001 and 2003 and emphasis on road safety proved a useful means of masking the more disappointing results of government policy as a whole.

1.3 The flagship measure: Introduction of automated speed enforcement

Automated speed enforcement is without question the major, emblematic event of this decade of change in road safety policy in France. Sophisticated checking technology has been introduced and the road toll has shown considerable improvement, with the annual number of deaths down by almost 40% since 2002.

In 1999 the Interdepartmental Road Safety Committee (CISR) set out to enhance the effectiveness of speed checks by providing the police with more sophisticated equipment and resorting to automation of checks (ONISR 2001, p. 23). In this respect it was making use of an earlier suggestion which the authorities had until then not put into practice (Commission de la sécurité routière 1989, p. 33; Namias 1994, p. 23).9

In December 2002 the CISR decided to install an automated speed enforcement system. Tests began early in 2003, with the first devices being officially put into use by the minister of transport and the minister of the interior10 in November 2003. Installation of the devices then went ahead at the rate of some 500 per year. In January 2009 the CISR decided to continue at this pace until 2012: by then France will have 4500 such devices, some of which will be used for red-light checks. Automated enforcement is seen as contributing to a cut in the road toll in line with the official goal of a reduction to 3000 deaths annually by 2012.

Automation allows for two detection strategies. The first uses fixed devices which function autonomously and continuously and whose presence is indicated by a standardised signing system. The authorities' aim here was to generate broad deterrence, educate the public and bring lasting change to driving practices. This approach was also a means of gaining public acceptance for the system and to avoid its becoming a focus for discontent as a new kind of tax. The mobile devices, by contrast, function discontinuously and their operation requires the presence of police officers; they are not signalled and are concealed in unmarked cars. The goal here is to produce specific deterrence and to identify and punish offenders. Fixed devices currently represent some two-thirds of the total.

Use of the devices is backed up by an (almost totally) automated detection/sanction system made possible by digital technology (for the photos) and computerisation (for the processing and transmission of data). Thus an offender can be detected by an automatic radar device, then pay his fine, without the least contact with a representative of the state. The resultant dematerialisation of the legal proceedings reduces the possibility not only of various "parasitic" practices – latitude, leniency, abandoning of cases under the statute of limitations – but also of variations in penalties (Carnis 2001, Pérez-Diaz 1998, Barberger 1992). This detection/sanction method represents a marked change from previous practice in that it involves integration of the checking and punitive tasks,11 together with the technical capacity to deal with the mass of offences constituted by speeding violations. Thus, between 2003 and

9 These reports argued for automation of speed checks, whereas the system now in use involves automation of both checks and penalties.
10 Nicolas Sarkozy, who would be elected President of France in May 2007.
11 The handwritten speeding ticket is no longer used.
2008, over 57 million infractions were recorded by the devices and almost 28 million of them processed via the system.\textsuperscript{12} The average processing period is less than a week and the number of challenges by drivers is insignificant.

2 The deterrence policy: a "revolution" on the march

The organisation of the deterrence policy has undergone marked changes over the last few years. Implementation of the system has led to automation of speed checks, but has also had an impact on operational organisation. The number of violations detected has risen steeply and a new distribution of roles has taken place.

2.1. Reorganisation of traffic violation checks

The implementation of an automated speed enforcement system represents a major institutional innovation, and one which has brought substantial change to the way speed limit enforcement was previously organised.

There now exists a distinction between violations whose identification and sanctioning involve an automated process and those for which the process is "manual". In 1998 18.8 million violations of the traffic code were detected, with the figure rising to 20.4 million in 2008: a rise of some 8.5\% in relation to 1998, but of 16\% in relation to 2001, the year with the lowest number of detected violations. In 2008 automatically processed violations accounted for approximately 38\% of the total,\textsuperscript{13} in other words, more than one violation in three is now out of the hands of the police. Furthermore, over 44\% of the violations identified have to do with speeding, whereas this category was barely 8\% of the total in 1998. This rise in the proportion of speeding violations does not mean that drivers are now less inclined to stick to the speed limit rules: it is simply an indication of the efficiency of automated devices in mass detection of certain behaviours. In the years to come automation of red-light enforcement and even of illegal parking detection is going to increase the proportion of automatically detected offences (Carnis 2009a, p. 30), and automated processing will thus become the norm.

There have also been notable changes in the institutional organisation of speed limit enforcement. The automatic speed enforcement system is a form of organisation additional to that of the two major policing bodies: the Gendarmerie, which covers rural and periurban areas (95\% of French territory), and the police forces working in the cities. Each has a traffic policing function within its specific jurisdiction, while the automated system covers the entire national territory and knows no jurisdictional limits as such. Without going into the details, it should be noted that the automated enforcement system is markedly centralised around two major bodies: the Interdepartmental Automatic Speed Enforcement Project (DPICA), responsible for the strategic decisions, operational emphases and overall piloting of the system; and the National Treatment Centre (CNT) in Rennes, in charge of the legal and information technology handling of violations (Carnis 2008b). Thus the organisational system is a three-tier one.

Another three-part structure has taken shape in respect of deterrence. Manual checks are always undertaken by members of the police or the Gendarmerie, with the latter body estimating traffic work as representing around 20\% of its overall activity. With regard to automated enforcement, part is carried out using fixed apparatuses and the rest with mobile equipment whose operation is in the hands of the Gendarmerie and the police.

\footnote{12\} Certain violations cannot be legally followed up because the photos are defective or foreign drivers cannot be identified.

\footnote{13\} These are speeding violations only.
2.2. The evolution of enforcement: an increasingly greater role

The number of identified speeding offences increased nine-fold between 1998 and 2008, a change basically due to the substantial contribution of the automated enforcement system, which accounts for over 85% of the total (figure 1). The number of infractions recorded by the police has not suffered greatly from the introduction of automation, with a total of some 1.3 million for 2008 – a slight downturn from 2004–05, when the figure was 1.8 million. This change may be explicable in terms of the increasing use of mobile devices since 2006: more manpower has been allotted to this task, the result being a decrease in "manual" enforcement activity. The fall in the number of speeding offences can also explain in part the observed fall in the overall number of traffic violations.

![Figure 1: Changes in the number of speed limit violations according to the mode of detection (2003–2009)](Source: ONISR 2009, Observatoire des Vitesses)

The number of offences registered by the automated system rises each year, with an increase of 16.7% from 2007 to 2008. However, this rise does not mean that the system fails to deter excess speeds; rather it is explained by the ongoing installation of new devices. The average number of violations detected by each device actually decreases every year, with a drop of 46% between 2005 and 2008. This change should be compared with the traffic work of the police, who have received no additional financing for their manual road safety tasks.

Also highly revelatory is an examination of the changes in non-ASE speed limit violations in terms of their seriousness (Figure 2). Violations of 30 kph and more peaked in 1998 at 48% of the total. By 2008 they accounted for no more than some 16% of all manually detected infractions. Their number began to decrease in 2002, when violations of 20–30 kph became the most numerous, with their culmination coming in 2004, when they were 40% of the total. Violations of less than 20 kph rose rapidly over this period, reaching a ceiling of over 500,000 in 2005. Their number then declined. Whereas they represented 6% of all infractions in 1998, they were running at 30% in 2008. Since 2004 minor speed violations (<20 kph) have outstripped major ones (>30 kph).
These respective changes highlight the deterrent effect produced by the new enforcement policy, with violations tending more and more towards the less serious categories. This view is confirmed by the DPICA statistics on the distribution of speeding violations according to their level of seriousness. For the period 2003–2008 more than 90% of violations detected by automated devices were of less than 20 kph, with the highest excess speeds representing barely 3% of the total.

The new deterrence policy put into effect over the last ten years has worked relatively well: extreme excess speeds have virtually disappeared. At the same time the sheer number of minor speeding offences also points up the end of the impunity that once prevailed (Carnis 2001, pp. 498-499). Other changes too deserve mention, among them the hike in the number of suspended driving licences caused by penalisation of excess speeds: in 1998 the total was 3,830, but by 2002 it had risen more than fourteen-fold to 55,950. By 2008, however, it was down to 29,555, a fall of over 50% that once again illustrated the deterrent effect of the change in policy. Between 1998 and 2008 the number of driving licence points lost more than trebled, with the number of drivers having lost all their points reaching 98,057 in 2008 – nine times more than in 1998. Thus the coercive activism of this last decade has resulted in the removal from the roads of a steadily increasing number of drivers considered as dangerous. This situation raises many issues for the authorities, who have to justify the retention of a highly coercive policy at a time when excess speed violations have very largely fallen into the lower categories.

2.3 Issues associated with continuance of traditional checks

The automation of speed checks that began late in 2003 did not lead to a reduction in the resources available for police road safety work. The relative stability of the violations detected manually suggests a possible association between the different techniques for producing deterrence. For example, one-third of all violations in excess of 30 kph are detected by the police. It should be noted that police work in this field is marked by an assessment margin that takes account of the circumstances under which the offence was committed. A police officer can apply powers of discernment not possessed by the automated device, which is perceived as "blind". More than 90% of ASE-registered violations involve minor excesses,

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14 This was an administrative penalty.
while almost 70% of those detected manually are over 20 kph. Thus two deterrence rationales are at work, which in fact turn out to be complementary. Automation enables mass processing of violations, leaving the police free to concentrate on the most dangerous behaviours and fine-tune the overall deterrence strategy. Since 1998 this has led to a 250% increase in the number of manually detected violations for speeds unsuited to specific traffic conditions – these being types of violations that cannot be detected by an automated enforcement system. There thus exists a real complementarity between the different modes of enforcement.

As a consequence a division of labour in terms of speed behaviour deterrence has gradually taken place in France over the last ten years. Not only has automation of enforcement not caused a drop-off in police traffic activity, it has enabled honing of working strategies by establishing complementarity between automated and manual speed checks.

3 Evolution of speeding behaviours

Changes in both driving speeds and compliance with speed limits show that there has been a real shift in attitude among road users. Lower average speeds, fewer speed limit violations and a significant reduction in the number of major speed infringements all point to the impact of a credible, effective public policy of deterrence – and this in spite of the unfavourable context that prevailed until 2001.

3.1 The overall evolution of speeding: the big shift of 2002

The increase in enforcement facilities generated a rise in the number of speed limit violations detected. However, closer analysis of these violations in terms of their seriousness has also brought to light the existence of behavioural adaptations. The change of behaviour in respect of speed choices can be evaluated via, among other things, an examination of the overall speed indicator, a weighted index taking account of the speeds of different vehicles on the country's different road networks (Figure 3). This indicator has fallen by 10 kph since its first use in 2002 – a drop of 12%. Prior research has demonstrated the close correlation between changes in traffic speeds and speed limit enforcement both automated and manual (Carnis 2008b). 80% of the gains in terms of speed reduction, as illustrated by the changes to this indicator, were achieved between 2002 and 2005, while those obtained since then are steadily less. Thus a speed enforcement system presents a diminishing marginal return in terms of effectiveness (Carnis 2009b), a datum that must be taken into account by the authorities in respect of the future emphasis they envisage for the speeding deterrence system.

![Figure 3: Average Speed for Private Cars for the Whole French Road Network (2002-2009)](Source : ONISR 2009, Observatoire des vitesses)
The favourable changes with regard to speeding since 2002 mark a break with the first half of the decade under study. Since 1996 speed behaviours in France had been deteriorating on most road networks and among the different types of road users (ONISR 2001, pp. 82 and ff). Thus between 1996 and 2001 the average speed for passenger cars during the day had risen by 7 kph on freeways and 2 kph on main highways. In the urban context it remained stable, but the overall trend was upwards. The new policy halted and then reversed this trend, while at the same time producing an improvement in speed-related behaviour.

It would seem that the creation of a number of tools – among them enforcement plans for the départements and the definition of new offences – had failed to lead to effective implementation of public anti-speeding policy (Chapelon 2008, p. 32): between 1999 and 2001 the number of hours devoted to speed checks by the police diminished by 27%. Thus 2002 stands out as marking a clear break not only in terms of driver behaviour, but also in respect of a public policy which then became credible and effective.

3.2. Excessive speed

The decrease in traffic speeds is a major feature of the period that began in 2002, and one that went hand in hand with another notable change: the fall in the number of extreme speed limit violations. While in the first four months of 2002 violations of 30 kph represented 7% of cases, the figure fell to 0.9% for the first four months of 2009 (Figure 4). This virtual disappearance of extreme excess speeds signals a change in the behaviour of road users, who have been deterred from going too far over the limit.

![Figure 4: Changes in extreme speed limit violations in France (2002–2009)](Source: ONISR, Observatoire des vitesses, 2009)

Analysis of the level of excess speed for the different categories of vehicles points to a general trend towards increased observance of the rules governing driving speeds since 2002 (Figure 5).
The proportion of cars driven at more than 10 kph over the speed limit fell from 37% early in 2002 to around 12% in early 2009 – a spectacular reduction of some 68%. A similar change was observed in the case of trucks: 65% over the same period. Even motorcycles showed a reduction of 46%, despite a disregard for speed limits significantly higher than among other road users. The actual figure was some 2.5 times that of cars and trucks, so the change of behaviour was less significant within this group. A partial explanation lies in the impossibility of identifying motorcycles: their licence plate being at the rear, they elude some automated devices, which take photos frontally. A more disquieting change, too, is an increase here of some 20% since the end of 2006.

Different effects are also observable when we analyse the evolution of speed excesses in terms of the type of road network (Figure 6). However, the continuing overall trend is towards a significant drop in excess speed levels for all networks. The decrease is more than 80% for main and secondary roads, while it is less marked in the case of freeways: 63% for...
the period 2002–early 2009. The excess speed level remains significantly higher on freeways than on the rest of the road network: twice that of main roads and four times that of secondary roads. This figure can be better appreciated in the light of the fact that 80% of fixed radar speed traps are on main and secondary roads, and only some 16% on the freeway network. The geographical strategy behind the deployment of automated devices has doubtless influenced the results obtained.

The evolution of traffic speeds signals a change in driver behaviour which took place in the course of 2002. The disappearance of major speed excesses and the fall in the number of infringements for all networks and all users reflect the operational use of new tools as part of the policy of coercion and the real effectiveness of the policy of deterrence.

Conclusion

The overall road safety situation has shown considerable improvement over the last ten years. These encouraging results can be partly explained by the implementation of a new policy of deterrence in respect of excess speed. New tools, heavier penalties, effective application of the law and the introduction of an automated speed enforcement system have changed driver behaviour in terms of speed choices and observance of the rules. Analysis of checking activity highlights the end of impunity for all speed limit violations, including those lowest on the scale.

This change of policy is clear evidence of a new approach to the handling of illegal behaviour. However, fresh questions have emerged regarding the political and social "sustainability" of this kind of public measure. Is coercion the only solution to the problems of behaviour on the roads? Will the authorities be able to pursue the intensification of their policy of deterrence given that future gains will inevitably show a decline? Will they come up with equally effective alternative policies regarding road safety? These are questions for which they will need to find answers rapidly.

References

Barberger Cécile (avec la collaboration de F. Durieux, I. Sillon et P. Vadrot), (1992), Contraventions au Code de la route et sécurité des personnes, La mise en œuvre paradoxale de la sanction des inobservations à la réglementation routière, Institut d'Etudes Judiciaires, Université Paris X, Décision d’aide à la recherche n° 90.0042.


From 1999 to 2008 edition of this yearbook were used.

AN ASSESSMENT OF ROAD SAFETY AND ACCIDENT POLICY TRANSITIONS AND PATHWAYS IN UGANDA: MILESTONES AND PRIORITIES FOR IMMEDIATE ACTION

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ABSTRACT
Road safety is a major concern on the sustainable development agenda of Uganda. According to the World Health Organization (WHO), motor vehicle crashes kill about 1.2 million people each year. That is set to rise to 2 million by 2020 unless new safety measures are taken, making road traffic injuries the third largest cause of death and disability. The main objective of this paper is to examine existing road safety instruments and rules in Uganda that can help us to understand factors that inhibit the effective transfer of road safety policy into effective action. The paper also draws priority areas that require immediate attention for enhancing traffic safety in the country. Instruments and rules aimed at enhancing road safety in Uganda over the last 20 years can be classified into two phases: 1] ‘ad hoc and ineffective road safety policy’ [1986-2003]; and 2] policy renaissance tools [2004 – to date]. These phases which this paper refers to as transitions; have shown characteristics of policy systems that are part-malfunctioning, part-wobbly, incomplete and part non-existent. Data available shows that road safety condition in Uganda is still unsatisfactory and road accidents, fatalities and injury have been increasing during the last 20 years. Uganda’s current fatality rate is estimated to be 61 road deaths per 10,000 vehicles (2007) with a 7% increase per year. Based on average cost per vehicle damaged of US$ 2,290, average fatality cost of US$ 8,600, and injury costs of US$ 1,933, road accidents cost the Ugandan economy US$ 101 million per year representing a cost of about 2.7% of the country’s GDP. This paper argues for a strong policy framework that should be integrated into the sustainable development framework for the country.

Key words: road safety, accidents, policy transitions, pathways, Uganda
1 INTRODUCTION
Road safety is a serious and growing concern in Uganda. The road transport system in Uganda is annually delivering a lot of casualties and injured people to the medical system and according to studies done by the Injury Control Centre Uganda [ICC-U] based on surveillance data since 1996, 45-50 percent of those coming to hospitals are road crash victims. Malaria, TB and HIV/Aids are still the biggest health problems with regard to raw numbers but in terms of resources used, road crash victims are the most costly. It has been estimated that road accidents in Uganda cost about 2.7% of our GDP in terms of lives, injury, vehicle and other property lost [Nasasira, 2009].

Data collection on road safety is poor by all accounts, with very little data, and little confidence in the integrity of the data that is collected [Arrive Alive Uganda, 2009]. Data about road accidents are reported to and maintained by local police, who in turn send them to police headquarters in Kampala City. These are later submitted to the Uganda Bureau of Statistics for the creation of a national database. Every effort was therefore made to capture police accident records under the collection of the Uganda Bureau of Statistics and Ministry of Works and Transport. Reference was made to the available laws, policies and action plans in place including: 1] the Traffic and Road Safety Act 1998; 2] National Road Safety Action Plan; 3] National Transport Master Plan; 4] Road Safety Review [2003]; and 4] The Ten-Year District, Urban and Community Access Roads Investment Plan [DUCARIP]. The next section addresses the drivers of accidents and fatalities in Uganda; sections three explores the major policy transitions in road safety in the country; with conclusions given in the last section.

2 ACCIDENTS IN UGANDA
It is said that Uganda’s road crash record is second worst on the African continent following Ethiopia. Fatalities and injury have been increasing during the last 10 years. In 2000 there were 14,390 reported accidents with 1,438 fatalities and 12,946 injuries compared to 2008 which had 18,250 reported accidents, 2,334 fatalities and 12,076 injuries. This shows an increase of 62% in 8 years or 7% per year. Table 1 shows accident statistics for Uganda between 2005 and 2006 by major cause. It is important to note that during the period 2000 to 2008, the vehicles on our roads doubled. Statistically, the fatalities per 10,000 vehicles reduced from 88 in 2000 to 64 in 2007. A transport expert shared the following comparison. “Considering only 600,000 car ownerships in Uganda the number of 3000 is extraordinary. In my country (Japan) 5000 die every year from a car ownership of more than 70 million.” With the growth of automobile and motorcycle use, this toll is expected to rise dramatically harming the prospects for health and economic growth for Ugandan road users, especially youth [Arrive Alive Uganda, 2009].

Accidents in Uganda according to Naddumba [2008] are a result of rapid motorization and urbanization in a country with a poor economy. According to Itazi [2009], the causes of road accidents in Uganda can be classified into:
1. Human error which accounts for about 80% of the road traffic crashes. (This includes reckless driving, over speeding, inconsiderate use of the road, careless or ignorant pedestrians, incompetent drivers and driving under the influence of alcohol or drugs.)
2. Defective vehicle condition which accounts for about 10%, (include defective brakes, steering, suspension, worn out tyres, defective lights, indicators and engine among others.)
3. Environment factors which account for about 5% (include weather conditions and activities along the road such as road repairs, grazing of cattle along side the road and road side markets.)

4. Road condition which also accounts for about 5%, (include bad road surface, pot holes and poor road designs and inadequate road furniture. Road geometrical characteristics also influence accident occurrence at points like sharp corners, steep hills and intersections.)

Table 1: Causes of road accidents in Uganda [2005-2006]

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Uganda Police Records [Data from UBOS, 2009]

Figure 1 shows the number of accidents and fatalities in Uganda between 1990 and 2005. It illustrates a significant drop, of about 42 percent, in the number of road accident cases reported between 2006 and 2008. In 2008 about 12,000 road accident cases were reported, of which 77 percent were still under investigations and 23 percent were prosecuted in courts of law. Figure 2 further shows the rate of motorization on the country’s roads while Figure 3 shows the ratio of accidents and fatalities per vehicles on Ugandan roads.

In Kampala, road traffic accidents account for 39% of all injuries, primarily in males aged 16–44 years [Naddumba, 2008]. Drivers constituted the least percentage of persons killed, while pedestrians were the largest group of persons killed in the same period. Between 2007 and 2008, pedestrians registered the highest percentage decline (23 percent) of all persons killed by road user type [Figure 4].
Figure 1: Number of road accidents and fatalities in Uganda 1990-2008 [Data from UBOS, 2009]

Figure 2: Number of accidents and rate of motorization on Ugandan roads [Data from UBOS, 2009]
Over the years there have been several attempts to curb road accidents in the country. This has led to various measures being put in place. At closer look, most of these measures have been put in place after an accident claimed many lives or a prominent government official. The instruments and rules aimed at enhancing road safety in Uganda over the last 20 years can be classified into three phases: 1] ‘ad hoc and laissez faire policy practices’ [1986-1998]; 2] ‘command and control’ and policy fixation [1999 – 2003]; and, 3] policy renaissance tools [2004 – to date].
3 POLICY TRANSITIONS IN ROAD SAFETY IN UGANDA

Policies aimed at enhancing road safety in Uganda over the last 20 years can be classified into two phases: 1] ‘ad hoc and ineffective road safety policy’ [1986-2003]; and 2] policy renaissance tools [2004 – to date]. These phases which this paper refers to as transitions; have shown characteristics of policy systems that are part-malfunctioning, part-wobbly, incomplete and part non-existent. The characteristics of each of these phases are addressed in detail in the next section.

3.1 ADHOC AND INEFFECTIVE ROAD SAFETY POLICY [1986 – 2003]

The policies that existed during this time were heavily based on colonial motor vehicle codes and had been outdated and inappropriate for controlling traffic and improving road safety. The policies were developed when there were few cars and traffic conflicts were not a serious issue. While the inadequacies of traffic legislation were clear, traffic enforcement in Uganda primarily consisted of stationing foot patrols on traffic islands at busy intersections. However, there were reported increases in the number of road accidents in the country. This was compounded by a situation where most of the roads in the country shared a common characteristic of being unsafe at any speed, at any time of the day. Road components and structures were of the low quality. Also, the poor standard of road infrastructure like guard railings/barriers; pavement marking and signs; illumination levels, traffic signals, horizontal/vertical alignment and sight lines contributed largely to the carnage on the Ugandan road network. Roads were without signs. Streets lights, traffic lights, packing facilities, pedestrian/cyclist facilities, road marking and painting were poorly maintained. This trend persisted since the government authorities relegated road safety issues to the periphery. For all intent and purposes, inadequacies on road infrastructure were rarely attended to, until it became a death trap.

Onakomaiya [1988], portrays the ugly picture of the road traffic environment in Nigeria; which is very applicable in Uganda, thus “... when you have a combination of largely illiterate or inexperienced or drunken or over-confident drivers, unconcerned about the lives of other road users, operating poorly-maintained vehicles, on high quality but poorly designed and illmaintained roads, that are ridden with all kinds of hazards and obstruction, in a society that is devoid of traffic law enforcement services, and that is ill-equipped with emergency road safety facilities, where government, police and military drivers flout traffic laws with impunity, where paramedical personnel are sometimes cold and unconcerned about the agonies of road accident victims, and where the relevant government authorities merely pay lip service to road safety, you have the best conditions for maximum accident rates with attendant high fatality, casualty and non-survival indices ....”

Data from the Ugandan Ministry of Works indicated an average annual rate of growth of traffic volume of 13% over the 5 year period and the average number of crashes (any type) per road on the surveyed roads increased by 6% per year. During this phase, the Government of Uganda produced a series of legislation including the Traffic and Road Safety Act, 1998, which regulates registration and licensing of motorvehicles, and establishes the Transport Licensing Board [TLB] and National Roads Safety Council [NRSC]. With these new regulations, there was no effective follow up with implementation. In 2000 the Government of Uganda developed a five year road safety program with a three year National Road Safety Action Plan whose
implementation started in 2004. This action plan has a three pronged approach namely: 1] capacity building in the form of institutional support; 2] physical improvement of roads and the removal of some critical black spots on major road corridors; and 3] enhancement of enforcement

3.2 POLICY RENAISSANCE [2004 – TO DATE]

Amid concerns that Uganda’s road carnage was getting out of hand, the government in 2006 started enforcing the no-nonsense road safety measures stemming from the 1998 Traffic and Road Safety Act. The Ugandan Police department deployed enhanced traffic safety patrols on the four major roads to the capital Kampala.

In 2004 the police department acquired four patrol cars and equipped them with speed detecting radar. They hired and trained 20 traffic officers to be deployed in mobile teams. In October 2004 they began daily enforcement of traffic regulations on the four main roads leading into Kampala city. The four teams carried out their enforcement efforts each day of the week from 06:00 to 18:30. The squads would alter their location on a daily basis and split the task of identifying violators and flagging them to stop, among the members of the team. Each team was trained and equipped to use a Doppler radar to measure speeds, but teams noted delays in servicing the radars that broke down. In practice the violations that officers tended to enforce were unsafe loading, careless driving and speeding (on days when the radar devices were operational). After a motorist was stopped, they could be additionally cited for license violations or alcohol intoxication if these became apparent. Patrol cars were often pressed into good Samaritan service as makeshift ambulances, although neither the vehicles nor the officers were formally outfitted for pre-hospital care [Bishai, et al., 2008]. The total number of crashes per road (any type) fell by 11%. If one uses the official estimates of traffic volume as the denominators to compute annual estimates of crashes per vehicle, then crash rates per 1000 vehicles were falling at a rate of 1% and 9% per year in the pre and post intervention period respectively [Bishai, 2008].

A new Highway Code was introduced in 2004 and has now been translated into local languages. Road Safety has been introduced in Primary School Curriculum. Syllabi for drivers and instructors have been developed and will be introduced this year [Nasasira, 2009]. A national road safety policy and strategy has also been prepared with the assistance of the World Bank under the TSDP 2009 - 2014. This policy will help define current weaknesses and how to address them, assign responsibility, monitor performance and evaluate road safety policy needs. Since 2004 key regulations to mitigate accident occurrences and improve on road safety have been made. These include:

3.3.1 SEATBELTS

The government came out strongly on the use of seat belts only after the Speaker of Parliament had died in a car crash. It was said that he was thrown out of the car because he wasn’t wearing...

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1 Uganda is a multilingual society and the main official, policy and legal language is English. However, since many sections of society do not comprehend English, the National Road Safety Council has felt it important to have all road safety legislation translated into the local language.
a seat belt. After this accident, everyone traveling in a vehicle was ordered to wear a seat belt. Primary enforcement provisions permitted law enforcement officers to stop a vehicle on the basis of observing a seat belt violation. Sometimes, this would be done by secondary enforcement provisions, requiring law enforcement officers to have another reason for stopping vehicles, before siting occupants for seat belt violation. The Police were at the centre of this initiative, treating harshly drivers and passengers who did not comply. Several people were arrested on the spot and taken to court, and for a while almost everyone traveling in a vehicle was seen comfortably belted up. These seat belt laws were observed to have increased day time seat belt use, but there was little data to support that such laws have any impacts on night time seat belt use. A few months down the road, complacency set in and the public started ignoring the new set of rules. Today, this is one of the areas given the lowest priority despite the fact that seat belts have been proven to have an enormous life saving potential. The traffic police officers dont look bothered any more and some of the seat belts used have been described as “death belts”, with those made from bags simply small and inelastic.

3.3.2 CRASH HELMETS
With the increase in demand for motor cycle [locally referred to as boda-boda] services in the country as a quick get-around means of transport, there was also an increase in the number of motorcycles and their riders. The Ministry of Works and Transport passed the 2004 Traffic and Road Safety (Motorcycles) Regulations, ordering motorcyclists to wear bright colored clothing whenever riding, and crash helmets for both riders and passengers. This provision also prohibits carriage of more than one person on a motorcycle. A fine of between Shs 40,000 [$20] and Shs 80,000 [$40], or imprisonment not exceeding one month, awaits a rider who violates these rules, and a Shs 20,000 [$10] fine or imprisonment of not less than one month or both, for stubborn passengers. This was resisted by the riders who said they were expensive to purchase. Most people see sharing of crash helmets as un-hygienic and inconveniencing. It is mainly resisted by women who argue that the helmets would spoil their hair. Others reports and concerns from several quarters indicate that traffic legislation is unrealistic and impractical. They question how many people would be comfortable using helmets used by all people, or can carry their own. As a result, the campaign lost steam before it could even work. It has also been reported that most motorcyclists use of wrong products, for example using builders’ helmets as crash helmets.

3.3.3 SPEED GOVERNORS AND SPEED GUNS
Speeding is one of the most important cause of traffic death and injury across the country. Speed limits were introduced at the height of increasing accidents involving Public Service Vehicles, especially the omni-buses (kamunye) and buses. A serious effort was made to encourage the installation of speed governors in vehicles and use of speed guns by police officers mainly at high risk sites. Speed guns include devices and safety cameras that measure the average speed over a certain distance from the front of the car. Speed guns are operated by police officers at the roadside and these can be deployed to different locations according to need. The speed governors would limit the speed of these vehicles to 80KM/H. This met a lot of resistance, with taxi, bus and truck drivers claiming short notice, the gadgets being expensive, and allegedly bad for their vehicles. In fact, taxi drivers went on strike for a short while. With the threat of strikes countrywide, the regulation which is covered under section 120 of the Traffic and Road Safety Act of 1998 with its punitive fines at between Shs 300,000 [$150] and Shs 120,0000 [$600],
and/or two years imprisonment, was set aside. To supplement this measure, Traffic Police were to be armed with speed guns which are used on highways to determine an on-coming vehicle’s speed.

3.3.4 BREATHALYZERS
Having noticed that most accidents in the night were being caused by drunken drivers, the government introduced breathalyzers that would be used to test the level of alcohol in the blood of a driver. This is covered under section 114 of the Traffic and Road Safety Act 1998 which gives express powers to a Police officer to carry out a test on any person that the officer thinks is driving under the influence of alcohol or a drug. Police were empowered to stop and breath-test drivers at random, without the driver revealing any suspicious behaviour. These so called random tests largely focused on times and places where drinking drivers were likely to be found [target driving]. The penalties for this offence range between Shs 100,000 [$50] and Shs 1.2 million shillings [$600], or imprisonment of between six months and two years, or both. This had an immediate impact as many drivers opted to take cabs rather than be caught and subjected to the humiliating alcohol test. However, implementation of this measure didn’t last long as the night checks stopped and drink driving resumed in earnest. Some circles had it that the Police had run out of the testing kits and there was no money to purchase more.

3.3.5 REFLECTIVE RED TRIANGLES
These were introduced to help drivers establish that the vehicle ahead of them had broken down, to avoid the possibility of ramming into it. At the time of their introduction, there had been many reported cases of fatal accidents as many drivers rammed into stationary or broken down vehicles. In several cases Police took action against drivers who didn’t have them in their vehicles. For a while motorists complied until they realized Police had lost interest. The gadgets were abandoned. Very few broken down vehicles use them these days.

3.3.6 SPEAKING ON PHONE
The law on talking on phone while driving also exists and was at one time vigorously pursued, but it has since been forgotten. In fact, it is mainly left to Police Patrol officers who use it to extort some little bribes from errant drivers. Laws don’t die but sometimes the enforcement slows down, sometimes it picks up, depending on the need to enforce it at any one particular time.

3.3.7 BLACK SPOT IMPROVEMENTS
Along three road corridors; Kampala – Jinja, Kampala – Entebbe, and Kampala-Masaka, eight types of deficiencies were identified. These deficiencies occur throughout the entire length of the paved classified road network, and they include:
- Inadequate or inappropriate pavement markings, road signs and direction signs
- Inadequate night time road delineation;
- Ineffective or non existent speed limit zones;
- Inadequate main road access control;
- Inadequate differentiation of road standards between urban and rural environments;
- Inadequate pedestrian separation in urban and commercial areas and intrusion of commercial activities into road space;
- Inadequate provision and inappropriate use of public transport stopping areas and areas for passenger transfer.

The Road Safety Audit and Improvement Study carried out under the Ten-Year Road Sector Development Programme, 1996-2006, identified 58 accident black spots some represented in Figure 6. This led to a programme of spot improvements, which no doubt must have contributed to a slight improvement in the number of fatalities per 10,000 vehicles.

Figure 6: Major black spots on Ugandan roads

Results from Bishai et al. [2008] indicate that traffic enforcement saves lives at a cost of $27 per discounted life year saved would rank this intervention among the most cost-effective public health interventions [Table 2]. The estimate of $603 per death averted is higher than the estimate of $313 per death averted from traffic enforcement in Africa based on extrapolation and modeling. The earlier estimate extrapolated a 25% reduction in fatalities reported from Brazil.
and estimated costs based on a theoretical model of what it might cost to increase traffic enforcement in the average sub-Saharan African country. The present estimate represents a substantial methodological improvement, because the effects and costs are estimated directly from Ugandan field data.

The annual cost of deploying the four squads of traffic patrols (20 officers, four vehicles, equipment, and administration) is estimated at $72,000. Since deployment, the number of citations has increased substantially with a value of $327,311 annually. Monthly crash data pre- and post-intervention show a statistically significant 17% drop in road deaths after the intervention. The average cost-effectiveness of better road safety enforcement in Uganda is $603 per death averted or $27 per life year saved discounted at 3% [Bishai, et al., 2008].

3.3.7 EXPRESS PENALTY SCHEME
The fees are provided for in the traffic Act for motorists caught in breach of certain sections. About 46,000 offences were reported in 2008 under the Express Penalty scheme [EPS], which was a reduction of 18% from 2007. This reduction was achieved as a result of the vigorous implementation of a Traffic Operational Policing Plan [TOPP Plan] which emphasizes public awareness on road safety countrywide.

3.3.8 INFORMATION AND AWARENESS CAMPAIGNS
Recognizing the grave situation caused by the ever increasing traffic and the alarming rate of accidents, different organisations around the country have organised different campaigns and events to raise awareness about road safety among communities living beside various highways in the country. The government is committed to developing strategies to combat the twin menace of aggressive driving and lack of safety awareness and taxi drivers have been used to distribute safety brochures in order to educate and positively influence parents and guardians, thus aiding them in reducing the number of fatalities and injuries.

Figure 8: One of the road safety awareness billboards in Kampala City
4 CONCLUSION

Despite substantial gains in road safety over the last three years, crashes and the resultant injuries still remain a major concern in Uganda. As the rate of motorization increases, population growth and reliance on cars increases, a large number of persons will continue to be exposed to the risk of accidents. While there are some basic traffic safety laws, enforcement is extremely limited by a lack of equipment, and lack of adequate training and management. The policy framework continues to be bedeviled with inadequate enforcement personnel, laxity among the enforcement personnel, low cooperation from the general public and inadequate road furniture. The process for acquiring a driver’s license is flawed, and there is no standardized training or testing to ensure that drivers and vehicles are roadready. Conflict will always exist between the goals of mobility and goals of safety and this balance needs to be continually evaluated. Safety should be considered as a critical element across all modes of transportation in the country. There is a need to improve the enforcement of traffic safety measures in country.

5 REFERENCES

Arrive Alive Uganda [2009], Fundraising for A Road safety Media Campaign-2009
GTZ [2006], The Road Safety Cent: Management and Financing of Road Safety in Low Income Countries, Eschborn Germany
Itazi, G. J [ 2009], ‘Example of Road Safety Interventions – Uganda’ Presentation at the Make Roads Safe Road Safety Conference Dar-es-Salaam, Call for a Decade of Action for Road Safety Tanzania 7th – 11th July 2009
Naddumba, E. K. [………], A Cross Sectional Retrospective Study of Boda Boda Injuries at Mulago Hospital in Kampala Uganda
Onakomaiya, S.O., [1988], Unsafe at any speed, An inaugural lecture, University of Ilorin, Nigeria

Transport Research Board [2006], *Improving Road Safety in Developing Countries: Opportunities for U.S. Cooperation and Engagement*: workshop summary / Planning Committee for the Workshop on Traffic Safety in Developing Nations Special Report 287 Washington D.C.

UBOS [2009], *Statistical Abstract 2009* Kampala Uganda

USAID [2005], *Road safety along the Northern Corridor: Good Practices Guide*. The ECA Trade Hub Nairobi Kenya

US Department of Transportation [2008], *Making the Case for Transportation Safety – Ideas for Decision Makers* New Jersey Ave, SE Washington, DC

ASSESSMENT OF TRAFFIC MONITORING TECHNOLOGIES OF RELEVANCE TO TRAFFIC SAFETY IN THE UAE

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ABSTRACT
This paper discusses the state of using modern traffic monitoring technologies for traffic safety applications in the UAE. It summarizes the opinions of operators and experts on the goals, functions, qualitative level of performance, and limitations of the existing UAE traffic monitoring technologies. The study also highlights suggested preconditions for adopting the latest technologies in the field. The opinions of the respondents were collected through an interview questionnaire which followed a stated preference survey type. It is agreed by the majority of the respondents that the actual traffic violations are higher than what is being actually detected by the existing monitoring technologies. Thus, there is a great potential for using the latest ITS technologies for traffic safety and management purposes. ITS policy should be framed within the context of how technologies address transportation problems or serve clear policy goals in traffic safety. With some preconditions, methods of implementing ITS technologies coupled with human monitoring for stringent traffic law enforcement should receive particular attention to serve a broad range of communities. Both ITS field tests of pilot projects and studies that generate data on traffic violations and safety impacts of the ITS technologies should continue. Studies and campaigns also need to be conducted on the public acceptance of ITS applications in the UAE. Police/transport authorities should enhance the inclusion of other stakeholders into the ITS policy discussions and share traffic data through a common electronic database.
1 INTRODUCTION

Police monitoring for effective and efficient enforcement of laws relevant to traffic safety is of great concern all over the world. Traffic safety concerns correlate the necessity of traffic monitoring and traffic law enforcement with the improved tools and technologies, for the reduction of traffic violations and accident rates. The World Health Organization Global Status Report (2009) on road safety states that the UAE road users are almost seven times more likely to be killed than those in the UK.

The UAE is suffering from a huge number of traffic violations every year. As reported by the UAE Ministry of Interior (2005-2008), the number of speed violations detected by the radars in the UAE in 2005-2008 was about 67.0% of the total reported traffic violations. In 2008, the UAE Government has undertaken considerable measures for punishing excess speed violators in terms of high fines and black points. After this, the number of speed violations has been reduced in the country, but still not to a significant level (52.9%). The number of accidents caused by over speeding in the UAE was 7.1% in 2005 and remained almost the same (5.7% in 2006 and 6.0% in 2007) until 2008. As such, there is an immediate need to assess the effectiveness of the existing traffic monitoring technologies in the country. Meanwhile, there is a need to study the implications and set the conditions that would suit the application of new traffic monitoring techniques.

Automated enforcement can be used to combat aggressive driving behaviors such as speeding or running red lights (Decina et al., 2007). For example, red light cameras have been found to decrease the number of red-light violators between ca. 20 and 80% (Arup, 1992; Chin, 1989; Retting et al., 2008). Intensification of enforcement and penalties in France was achieved through introduction of automatic enforcement and penalty systems for speed violations (Global Road Safety Partnership Report, 2008). As a result, fatal and injury crashes decreased in the vicinity (6 km) of fixed cameras by 40 to 65% during 2004 to 2007. Also, the rate of excessive speeding (more than 30 km/h over the limit) was reduced by a factor of five in that period. While these substantial improvements were not entirely due to the implementation of automatic speed control, the technology played a major role in this regard.

Recent enforcement-related ITS technologies could be found in Mimbela et al. (2007), Global Road Safety Partnership Report (2008) and TIPSOL Database (2009). Cordell et al. (2008) stated that civil traffic enforcement is now not simply a tool for ensuring compliance, but it has become an indispensable tool for extracting the maximum capacity out of the road network. Meanwhile, Wilson et al. (2009) conducted a comparison on how automated enforcement is approached in the European Union (EU) and the U.S. Since the late 1980s, automated enforcement has been widely used in the EU for detecting and prosecuting violations such as speeding and red light running. Legislation allowing automated enforcement has been primarily set at the national level, and as a result, a pan-EU type approval standard is not in place. In the U.S., automated enforcement was introduced in the 1980s for supporting a more efficient toll payment system. In the late 1980s, the technology was used for speed enforcement, and then red-light enforcement came about in the early 1990s. Individual states typically have the responsibility for enforcing most automated enforcement programs.

Pickworth et al. (2008) concluded that new technologies, such as satellite navigation and mobile phones, will provide information to motorists in new and varied forms. These authors emphasized the need to provide the right balance of information to ensure that information overload for the driver does not occur. Wigan et al. (2009) indicated that location is a critical aspect of both privacy and surveillance. However, before adopting latest ITS
technologies, a wider public and policy understanding of the implications of the expanding capacities to track, record and monitor location will be needed. This is because it is very difficult to reverse capacities once integrated into a wide range of commercial, enforcement and intelligence systems.

In the UAE, some traffic monitoring technologies in the form of radars and red-light running cameras are in use, especially in Abu Dhabi and Dubai Emirates. These technologies, however, were deployed without the necessary assessment studies on their effectiveness for appropriate enforcement policy purposes. In this study, a qualitative assessment of the existing ITS technologies in the UAE was conducted. One of the objectives of the study was to collect specific qualitative data from traffic safety and enforcement professionals of relevance to the use of ITS technologies in traffic monitoring and law enforcement. This was achieved using an interview questionnaire that includes the relevant aspect of this study. A second objective was to assess the current status of the traffic monitoring system in the country and to evaluate the performance of the system in light of the effectiveness of the existing technologies. This was determined from the perceived level of reductions of traffic violations after the installations of the existing technologies. A third objective was to assess the adequacy of the existing monitoring system. This was achieved by qualitative assessment of several aspects including the perceived coverage levels and the under-detection of traffic violations as well as the operational, technical, skilled personnel, organizational, economic and legislative aspects of the actual and intended use of traffic monitoring technologies. A fourth objective was to recommend some needed pre-conditions for adopting latest technologies in the UAE based on the weaknesses/limitations of such technologies.

2 DATA COLLECTION METHODOLOGY

2.1 Survey Design

The survey design adopted here is primarily the stated preference survey. In this type of survey, people are placed in hypothetical choice situations and asked what they would do if they were faced with this particular choice. Nowadays, the stated preference survey is considered as a proven methodology (Polak et al., 1995).

2.2 Survey Population, Sampling Procedure and Sample Size

The population of this survey consisted of experts and professionals working for the government and private sectors in the UAE in the field of traffic monitoring and traffic safety issues. Traffic law enforcement professionals, traffic engineers, and ITS experts were mostly selected as the target population of this study.

Traffic law and traffic safety professionals interviewed from various police departments, municipalities and other transport/traffic officials at each emirate. The sample participants’ duties could be found on the strategic level, such as ensuring interdepartmental cooperation, planning long-term goals, suggesting legal amendments and preparing drafts of legal projects, and being responsible for general public security and traffic, including planning and preparation of road traffic safety programs. Day-to-day duties include deploying the appropriate level of human resources, as well as the responsibility for crash statistics and data pertaining to enforcement, monitoring and patrolling. Traffic experts, professors and researchers from academic institutes were also considered to include their valuable opinions on this study.
In practice, assessment and recommendations of new technologies are commonly done by few experts or consultants using scientific approaches. Therefore, it is not essential to have a minimum number of respondents in case of the survey of traffic law enforcement professionals and experts. Nonetheless, a total of 43 surveys were completed in this study to satisfy the basic statistical minimum requirements of the sample size.

2.3 Data Requirements

The key items (to include in the survey) to assess the existing monitoring systems were extracted after a thorough review/analysis of the available police data and existing literature in relevant areas. Each interview questionnaire item was exactly designed to address a specific research question.

The qualitative survey questionnaire was developed to capture the various responses from the traffic enforcement professionals and experts. The stated preferences were selected based on the most common responses. In addition, open-ended comment area (for each question) was provided, where the respondents could provide their opinions if different from the provided list. As an example, in one of the survey questions, the participant was asked if he/she agrees on a list of objections/difficulties regarding the use of ITS techniques for traffic monitoring, and to tick the appropriate objection(s).

Objections against the use of technology were categorized into (a) technical and other practical difficulties; (b) wide use of the device would lead to opposite influences than intended; (c) opposition because technological solutions are inherently unjust, unfair etc.; (d) technology is too costly; (e) the effectiveness of technology driven enforcement has not been proven; (f) too strong social opposition to such measures, (g) too strong political opposition to such measures and (h) others. As can be seen, the question entailed closed and open parts to minimize the survey time, increase the understanding level of the question, and yet preserving the opportunity to express additional items of particular relevancy to the question.

3 FINDINGS OF THE SURVEY

3.1 Respondents’ Characteristics

All the respondents were somehow related to the traffic monitoring functions in order to support the current traffic law enforcement policies. Traffic-related professionals in almost all the major cities in the UAE have been covered by this study, with varying response rates. Of the total 43 respondents, 30% were from Abu Dhabi, 5% from Ajman, 23% from Al Ain, 12% from Dubai, 9% from Fujairah, 9% from Ras Al Khaima, 9% from Sharjah and 2% from Umm al Quwain. Among the notable professions, 37% of the total respondents are accident investigation officers from police (regularly involved in traffic law enforcement techniques), 9% are expert traffic consultants, 16% are heads of related departments or branches (involved in strategic planning), and 7% are traffic safety researchers.

The responses on the existing actual daily traffic monitoring functions of the respondents (Figure 1) include mostly enforcement of traffic law regulations (44%), accident/crash investigation (60%) and traffic management (42%). It should be realized that the use of ‘percentage of responses’ differs from that of ‘percentage of respondents’. Both are calculated on the basis of a total of 43 respondents. For the cases where each respondent could answer multiple options (i.e. either one or more than one) for a particular survey
question, then the ‘percentage of responses’ is used to show the distribution of responses. But, where each respondent could choose only a particular answer among all the options and sum up of all the responses percentages makes 100%, then only the ‘percentage of respondents’ is used for explanation.

Figure 1: Percentage of responses on traffic monitoring functions

Some specific questions were addressed to respondents of each specific area of the traffic monitoring functions. For example, respondents involved in the enforcement of traffic law regulations like police and those involved in road traffic surveillance for traffic violations and enforcement were asked about their strategic goals and policies, coverage, methods of traffic law enforcements, usage of ITS technologies and its limitations from operational, technical, skilled personnel, economy, organizational, legal and social perspectives. Accident or crash investigators from police, crash researchers and traffic safety engineers were asked about the methods of detecting accidents or incidents, the crash or incident response system, the crash recording and reporting system, and the crash investigating system from an engineering point-of-view. Traffic management and transport planning professionals were asked about their strategic goals and plans, current methods of traffic monitoring functions in their areas, the roadway infrastructure system to handle incidents or crashes, and the system to disseminate the incident information to road users. Traffic education/awareness professionals were asked about their strategic goals, plans and programs of awareness campaign, and the system to disseminate information to the public.

3.2 Traffic Monitoring Systems

3.2.1 Systems for Vehicle Detection and Identification of Violations

The percentage of responses on the existing systems being used (or intended for use) for vehicle or incident detection and/or identification of violations is shown in Figure 2. The
‘radar and laser’ technology-based system for the detection of speed violations was particularly selected by the majority of participants (72%) as most of Abu Dhabi, Dubai and Al Ain arterials and highways are equipped with speed-radar. Inductive loops are also in use in specific segments of the roadway networks. Video-based systems for the detections of violations or incidents were also selected by 26% of the respondents as video (CCTV) based system is already available primarily for security at some important infrastructures/places. However, there is almost no use of ‘in-car electronic violation detection’ system in the UAE, but some of the respondents intend to examine this on a pilot-scale.

![Figure 2: Percentage of responses on (A) system for incident/violations detection and (B) type of vehicle identification system](image)

3.2.2 Systems for Accident Notification and Location Identification

Responses on the existing techniques/technologies being used (or intended for use) for incident detection and/or identification of vehicle/violations are shown in Figure 3. Results indicate that the main accident notification system in use in the UAE is through the ‘999 calls’. Very few of the agencies use GPS system to identify the vehicle/incident location. The available incident detection system is through the CCTV monitoring from some of the traffic control centers in Dubai and Abu Dhabi. Some intend to use ‘automated incident detection’ system in TMCs. Also, for accident identification, there is no ‘in-vehicle collision alert’ system currently in use in the UAE, but some of the respondents intend to examine those on pilot-scales.
3.2.3 Systems for Information Dissemination to Public and Other Stakeholders

The distribution of the responses on the existing techniques/technologies being used (or intended for use) for systems to disseminate information to the public is shown in Figure 4. Respondents stated that internet websites (to inform the public regarding the traffic monitoring system) is the most common system (67% of the responses). Paper work and meeting are the main sources of information sharing between stakeholders. It is evident that there is a gap and a considerable room for improving the information dissemination system, as well as the level of communication and coordination with other stakeholders.

3.3 Perceived Performance of the Existing Traffic Monitoring Systems

The interviewees were asked to grade their agency’s level of performance (based on their work experiences on the existing monitoring technologies). Most of the respondents (53%) reported a ‘medium level or below’. A major portion (44%) of the respondents indicated a ‘not adequate enough’ existing traffic monitoring system because of its limited detection capabilities (existing systems can detect only 50% or less of the total actual traffic violations).
3.4 Suggested Monitoring Functions

The interviewees were asked to name the traffic violation(s) that should be strictly monitored. The responses were as follows:

- exceeding the speed limit by radar (65%)
- red light violations (40%)
- using mobile phone or car phone while driving (40%)
- following front vehicle closely (40%)
- not using seat belts (30%)
- heavy vehicles (in not-allowed places) (19%)

Figure 4: Percentage of responses on (A) system for information dissemination to the public and (B) means of communication and coordination with other stakeholders.
3.5 Suggested Monitoring Technologies with Pre-conditions

Most of the responses (56%) suggested integrating the existing techniques with the latest ITS technologies. The respondents were asked to name the latest monitoring technology that might be beneficial for traffic safety applications. The responses were as follows:

- tacho-graph to monitor driving patterns (53%)
- fixed speed limiters (44%)
- breath-test ignition-lock (40%)
- adaptable speed limiters (26%)

It is to be noted that most of the responses were related to tackling reckless drivers, who exceed speed limits, as this is one of the main concerns related to accidents and traffic violations. The main arterials and highways of Dubai and Abu Dhabi have got speed radars to catch offenders, but not all the emirates and all the major road links are equipped with radar systems. Also, speed cameras could only detect offenders nearby the radar location. So, aggressive drivers slow down at that point and are likely to over-speed again until the next radar location. Therefore, the number of recorded speed violations is probably far less than the actual number of violations. In this case, it would be beneficial to adopt a system that monitors and detects drivers’ past behaviour; for example, a tachometer that could be used to monitor targeted aggressive driver’s historical speed-data. Also, some other systems like average link speed cameras that could be utilized to monitor the average vehicle speed on a roadway link or a fixed speed-limiter that permits an allowable limit on a pre-defined speed limit link or adaptable speed limiters to have variable speed limit. Another significant response was regarding drunk-driving violation, where monitoring of such violation is not widely practiced in the UAE. Therefore, reporting of this traffic violation is under-represented in the traffic violations data, but significant responses from the respondents emphasized the need to have an automated ignition-lock system to prevent drunk-driving.

Several concerns or limitations on the use of ITS technologies were mentioned. The probable limitations/ weaknesses are as follows:

- ITS technologies are costly (35% of the responses)
- technical and other implementation difficulties (26% of the responses)
- privacy issues (23% of the responses)
- too strong social opposition on such measures (23% of the responses)
- technical solutions are unjust (12% of the responses)

Apart from the technical implementation difficulties, the responses also highlight other limitations of the suggested ITS technologies. For example, in case of an emergency, adhering to fixed speed limiters could result in a crash situation if there were scope to escape the situation with sudden over-speeding in a safer way. Privacy issue is of concern if someone feels that he or she is being monitored through radar, cameras, CCTV or with an electronic tag or tachometer. For the case of the UAE, some respondents suggested not to take photographs of traffic offenders from the front-side as the offender might be a female or an influential person. Alternatively, it was suggested to record the vehicle number-plate.
Some also feels that the technical solutions are unjust as they can not detect the humanitarian aspect in case of urgency. Therefore, these cases pose a challenge in the implementation of ITS technologies, as there might be a strong social opposition on the technical measures and hence social politics comes into play.

It is worth mentioning that only 42% of the responses of the respondents indicated that their agencies possess adequate technical and personal resources to adopt new technologies. Some respondents suggested pre-conditions (Figure 5) to be considered to increase public acceptance of latest intelligent systems. The most common response (53%) is to conduct research studies on the effectiveness of the ITS technologies. Another suggestion was to have a national wide registration of car owners. Here, all the emirates have their own car registration centers and all are connected with each other in terms of car identification databases. Others also suggested having a fully automated detection and processing of violations with the latest digital and wireless technologies. But, vehicle owners must be informed of these detecting technologies in advance and they need to be informed of the extra benefits regarding all stakeholders. Some also suggested having a transparent control strategy and use of revenues regarding the use of technologies.

![Figure 5: Percentage responses of the suggested pre-conditions for increasing acceptance for intelligent systems](image)

It is apparent that public decision makers should consider a balanced combination of technology and traditional on-road police control that would be productive after proper studies on the effectiveness on these technologies. In-vehicle driving-aid devices were regarded as an effective way to improve compliance with traffic laws. It should be emphasized that technologies may have some limitations in terms of targeted use and expenses. So, they should not be used as the only solution to improve traffic safety in the UAE. Rather they should be part of the overall safety policy-driven solutions. Each emirate should adopt more ITS technologies phase-by-phase for the most frequent and dangerous violations monitoring primarily in the areas of accident reductions, congestion reductions and incident management.
4 CONCLUSIONS

The existing traffic law enforcement monitoring techniques in the UAE are not adequate enough for effective reductions of violations and accidents as stated by most respondents. Coupling ITS technologies with human monitoring for stringent traffic law enforcement should receive particular attention. There is an urgent need to use more effective ITS technologies (for example, average link speed cameras for speed enforcement, GPS based location identification system, etc). Furthermore, the ITS policy should be framed within the context of how technologies address transportation problems or serve clear policy goals in traffic safety. The ITS program should adequately address social equity issues by conducting outreach efforts across a broad range of communities. ITS field tests as well as studies on traffic violations and safety impacts of the ITS technologies should continue and receive a nation-wide support. Particular studies are also needed on the public acceptance of ITS applications in the UAE. More campaigns with proper information dissemination technologies should be adopted. The underlying leading authorities (Police or Transport) should coordinate and actually involve other stakeholders (including the public) in forming the ITS policy development, deployment discussions, and accessibility to and sharing of data (such as violations).

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REFERENCES


Contents session 16  Traffic engineering innovations including road design and behavioural issues

Effects of Traffic and Geometric Features on Hazardous Manoeuvres
Francesco Bella, Department of Sciences of Civil Engineering/Roma TRE University, Italy

Different Designs of Cycle Tracks and Lanes – The Effect on Objective and Subjective Safety
Michael Sørensen, Institute of Transport Economics, Norway

A New Methodology for Implementing Road Design Guidelines in Thailand
Andreas Vesper, Bauhaus-University Weimar, Department of Transport Planning and Traffic Engineering, Germany

Drivers’ Risk Perception Assessment. The Case of Highways with Poor Geometric Characteristics, in Heavy Traffic Conditions
Prof. Nikolaos Eliou, University of Thessaly, Greece
ABSTRACT
The paper reports the outcomes of a large experimental study carried out using an advanced interactive driving simulator and aimed at analyzing the car-following behaviour and passing behaviour in different traffic conditions as well as different geometric configurations of the road alignment. A two-lane rural road more than 8 km long was designed and implemented in the driving simulator. The alignment had 15 different geometric elements: 8 tangents with length ranging between 200 m and 1000 m; 7 horizontal curves made up of approach clothoid, circular curve and departure clothoid. The radii of the circular curve ranged between 215 m and 1000 m. Four different traffic conditions in terms of traffic volume and speeds of opposing vehicles and impeding vehicles were simulated. Thirty-two drivers with ages ranging from 22 to 40, male (70%) and female (30%), drove in the simulator on the four scenarios. The differences in speed and position between the driver’s vehicle and the other vehicles on the road were collected in order to: a) identify the hazardous car-following and passing manoeuvres; b) calculate the parameters proposed in literature for the evaluation of the rear-end and head-on collision risk; c) evaluate the effects of traffic on driver behaviour during the two manoeuvres; d) analyze the influence of the geometric features of the road on the risk associated with car-following manoeuvre.

As regards the car following manoeuvres the measures of risk chosen in this study were the most advanced Time-to-Collision-based parameters: Time Exposed Time-to-collision (TET) and Time Integrated Time-to-collision (TIT). As regards the passing manoeuvres the evaluation of risk was entrusted to the remaining gap to the oncoming vehicle at the end of the passing manoeuvre.

The results of the correlation analysis between the rear-end risk parameters and traffic and geometric features suggest that the traffic conditions affect mainly the car-following behaviour. Also the geometric elements of the alignments have a significant role. Particularly the influence of the geometric features tends to stop when the traffic intensity reaches high levels. In these conditions the driver’s behaviour is affected exclusively by vehicle interferences.

Concerning the passing behaviour the outcomes of the analysis show that the accepted risk by driver increases as the traffic intensity increases. High traffic intensity leads the driver to carry out hazardous passing manoeuvres.
1 INTRODUCTION

The pursuit of higher safety standards involves a careful consideration of the interactions between the driver and the components of the road traffic system which affect the driver behaviour such as road geometry, traffic conditions, environmental factors (weather and pavement conditions) and vehicle features.

Several methodologies (see e.g. Lamm et al., 1999), based on the speed analysis of a vehicle in a free-flow condition, are available in literature for the evaluation of design consistency, aimed to promote driving behaviour in accordance with roadway’s geometric features and therefore avoid surprising events. These methodologies, analysing the road-driver informative process based on the condition of a free vehicle, represent a valid tool for evaluating alignments which are characterized by rather modest traffic volumes. However, disregarding the effects of the interactions among vehicles on driving behaviour, they are not effective for evaluating alignments with prevailing traffic conditions which are different from those of a free vehicle. In order to do this, it is essential to assess in which way driver behaviour is conditioned not only by the roadway’s geometry, but also by traffic. At this purpose several studies have been carried out which applied different indicators to identify the impacts of traffic on safety. These indicators can be attributed to three different approaches:

- the first approach includes the indicators based on the relative vehicle distances and speeds. These indicators allow us to analyse the interactions between two traffic components which are potentially in conflict during the car-following (Hayward, 1972; Van Der Horst and Hogema, 1993; Minderhoud and Bovy, 2001; Vogel, 2003; Kiefer et al., 2005; Lundgren and Tapani, 2006; Pham et al. 2008; De Mouzon et al., 2008; Zhang et al., 2008; Moon et al., 2009) and passing manoeuvres (Benedetto and De Blasis, 2003; Gray and Regan, 2005; Farah et al., 2008; Farah et al, 2009) (see next section background);
- the second approach allows us to identify the potentially dangerous traffic flow conditions that usually occur before an accident. The indicators which derive from this approach are based on the analysis of the speed variation experienced by drivers such as the Coefficient of Variation of Speed – CVS (Lee et al., 2002; Abdel-Aty and Pande, 2005) and the Acceleration Noise (Ko et al., 2006);
- the third approach consists of the indicators that allow a macroscopic analysis of traffic conditions such as average flow speed, traffic intensity and hourly traffic volume.

The first approach is the most widespread in literature in order to evaluate road safety under the effect of traffic interference on two-lane rural roads. On these roads the driver, who follows behind a slower vehicle, may assume two different behaviours: tolerating the slowing down imposed by the lead-vehicle or passing it.

The present study is carried out in this context. It deals with the car-following and passing manoeuvres which, if not performed correctly, give rise respectively to the most frequent accident: the rear-end collision and the head-on collision. In particular the study has been carried out in order to analyze the driver behaviour under the effect of the vehicle interference during the car-following and passing phases in different traffic intensities on a two-lane rural road. More specifically the objectives of the study were: a) to identify the hazardous car-following and passing manoeuvres through the computation of the indicators for the evaluation of the rear-end and head-on collision risk; b) to evaluate the effects of traffic on driver behaviour during the two manoeuvres; and c) to analyze the influence of the geometric features of the road on the risk associated with car-following manoeuvre.

Several studies in literature have shown that the car-following driver behaviour is affected, besides by the characteristics of the driver, also by traffic and road features (Ranney, 1999; Wang et al., 2003; Al-Kaisy and Karjala, 2008; Kim et al., 2009). However these studies have not extensively investigated the relationships between the indicators of the risk associated with car-following manoeuvres and the road geometry as well as the traffic conditions.
For the above-stated purposes an experimental study was carried out using the CRISS (Inter-University Research Center for Road Safety) interactive fixed-base driving simulator located at Roma TRE University. Advanced-interactive driving simulators are considered useful and reliable tools to assess driver behavior induced by the road environment. They allow a high degree of realism, a great versatility on reconstructing roads, low costs of experiments, an easy data collection, the highest safety for test drivers and the possibility of carrying out experiments in controlled conditions (weather, traffic, and drivers). For such benefits driving simulation systems have been widely applied beneficially in road safety analyses. (for exhaustive references see (Bella, 2009)).

The research was developed through the following steps:
- a driving simulator study (implementation in the driving simulator of a test alignment and four traffic scenarios, driving test and data collection);
- computation of the risk indicators;
- analysis of the relationships between the risk indicators and traffic intensity;
- definition of predicting models of rear-end risk indicators as a function of traffic intensity and geometric features of the road.

2 BACKGROUND

2.1 Risk analysis for car-following manoeuvres

Concerning the car-following conditions several indicators are available in literature to assess the rear-end collision risk that is associated with the manoeuvre. Among these are the Platoon Breaking Time Risk (PBTR) (De Mouzon et al., 2008), the Vehicle-Time-Spent-Following (Zhang et al., 2008) and the indicators based on the Time-To-Collision notion that are believed the most efficient. The Time-To-Collision notion was introduced by Hayward (1972) and afterwards applied in several studies (Van Der Horst and Hogema, 1993; Vogel, 2003; Kiefer et al., 2005; Pham et al. 2008; Moon et al., 2009) aiming at evaluating the rear-end collision risk in different road conditions (intersection, two-lane rural road, highways, in good and adverse visibility conditions).

Time-To-Collision (TTC) represents the time required for two successive vehicles, occupying the same lane, to collide if they continue at their present speed until the moment of the crash when vehicle \( (i) \) moves faster than preceding vehicle \( (i-1) \). Then:

\[
TTC_i = \frac{x_{i+1}(t) - x_i(t) - l_{ij}}{x_i(t) - x_{i-1}(t)}
\]

where \( \dot{x} \) denotes speed, \( x \) the position and \( l \) the vehicle length.

The higher a TTC-value, the safer a closing-in situation is.

In order to distinguish safe and unsafe approach conditions, a threshold value (TTC*) for the TTC should be established. The research activity carried out in this field points out that the threshold value ranges between 5 and 2 seconds (see e.g. Minderhoud and Bovy, 2001).

Based on the Time-To-Collision notion, two risk indicators were proposed by Minderhoud and Bovy in 2001: Time Exposed Time-to-collision (TET) and Time Integrated Time-to-collision (TIT).

The TET indicator expresses the total time spent in safety critical situations, characterized by TTC-value below the threshold value TTC*. It is assumed that TTC, at an instant \( t \), is kept constant for a small time step \( \tau_{sc} \). For the considered time period \( H \), there are \( T = H/\tau_{sc} \) time instants, to which the summation is extended while calculating the TET value. For each driver \( i \) we have:

\[
TET_i^* = \sum_{j=1}^{T} \delta_j(t) \cdot \tau_{sc}, \quad \delta_j(t) = \begin{cases} 1 & \forall \ 0 \leq TTC_i(t) \leq TTC^* \\ 0 & \text{else} \end{cases}
\]
The TIT indicator, evaluating the entity of the TTC lower than the threshold, allows to express the severity associated to the different conditions of approach that take place in time; for each driver \(i\) we have:

\[
TIT_i^* = \sum_{j=1}^{\bar{I}} \left[ \text{TTC}^* - \text{TTC}_i(j) \right]_{\text{sc}} , \quad \forall \ 0 \leq \text{TTC}_i(j) \leq \text{TTC}^* \tag{3}
\]

The superscript * indicates that the parameters have been calculated with respect to a prefixed threshold value.

The calculation modalities for the two indicators are illustrated in Figure 1, where five closing-in situations are displayed. Three of these become safety critical because TTC-values below the threshold value \(\text{TTC}^*\) (horizontal line) were collected. The TET indicator is the sum of the time travelled with subcritical TTC-values; the TIT indicator is the sum of the shaded areas.

Figure 1: Time-To-Collision profile and corresponding TTC-based safety indicators

It should be noted that the Time-To-Collision-based safety indicators for the single driver are calculated considering a specified time period (then for a certain road length); instead TTC refers to the condition in a single instant \(t\) (or in a single cross-section). Therefore TET\(_i\) and TIT\(_i\) allow us to obtain the car-following behavior, in terms of total time spent in safety critical situations and severity, of a single driver over a specified road length.

These indicators are considered the most effective safety indicators (Minderhoud and Bovy, 2001) (Lundgren and Tapani, 2006). In consideration of this, they were selected for the purposes of the present study.

2.2 Risk analysis for passing manoeuvres

Some studies have been carried out in scientific literature in order to evaluate driver behaviour during the passing manoeuvre and identify the factors that most affect it. Driving simulators were used for this aim. That because the driving simulators allow us to conduct the experiments in controlled conditions (geometric, traffic, etc.) and in total safety for the test drivers. A careful analysis of these studies pointed out the models and parameters able to assess the head-on collision risk which is associated with the passing manoeuvre.

In order to investigate a) driver decision making when passing a lead car in the presence of oncoming traffic and b) the effect on these processes of adaptation to closing speed, Gray and Regan (2005) compared the time required for the driver to overtake (TRO) with the time...
required for the oncoming vehicle to reach the point where the passing manoeuvre ends (TTC). This last time was obtained on the basis of the actual vehicle’s speed and distance at the instant of the beginning of the passing manoeuvre; TRO was calculated in function of a theoretical distance required to overtake. The authors found that a prolonged adaptation to closing speed produces a high number of unsafe manoeuvres, characterized by a significantly small value of TTC-TRO.

Farah, Bekhor and Polus (2009) developed a model able to predict the risk associated with the passing behaviour. The measure of risk that they selected was the remaining gap to the oncoming vehicle at the end of the passing manoeuvre. So the remaining gap is a time safety margin at the end of the passing manoeuvre, when the driver crosses the broken line separating the two lanes and returns to the right lane; from this instant onwards the trajectories of the two traffic components, the passing and oncoming vehicle, are no more potentially in conflict. The model appeared a useful tool to predict the risk on existing two-lane rural roads or new designed roads as a function of road features, traffic and drivers’ characteristics.

A further contribution was given by a study (Benedetto and De Blasiis, 2003) aimed to distinguish the safe passing manoeuvres from the unsafe ones. For this aim the authors compared the distance of the passing driver to the oncoming vehicle at the beginning of the manoeuvre with the sum of their breaking distances. The outcomes show how the accepted risk threshold during passing manoeuvre varies when the disturbing effects of an increasing traffic flow crucially change.

3 METHOD

3.1 Test Alignment
A two-lane rural road was designed and implemented in the driving simulator. The alignment was about 8.5 km long and was flat. The cross-section was 10.50 m wide (lane width 3.75 m and shoulder width 1.50 m). The alignment had 15 different geometric elements: 8 tangents with length ranging from 200 m to 1000 m; 7 curves made up of approach clothoid, circular curve and departure clothoid. The radii of the circular curve ranged from 215 m to 1000 m.

3.2 CRISS Driving Simulator
The simulation system of CRISS is an interactive fixed-base driving simulator, which includes a complete vehicle dynamics model based on the Non Linear Vehicle Dynamics Analysis computer simulation. The model has been adapted to run in real time and it has been validated extensively (Allen et al., 1998). The hardware consists of four networked computers and three interfaces. One computer processes the motion equations while the others generate the images. The hardware interfaces include a steering wheel, pedals and a gearshift lever. They are mounted on a real vehicle to reproduce a realistic driving environment (fig. 2).

Figure 2: CRISS driving simulator
The road scenario is projected onto three screens, one in front of the vehicle and two on each side. The usual field of view is 135°. The system is also equipped with a sound system reproducing the sounds of the engine. The whole system offers a very realistic simulation and it allows us to record many parameters related to travelling conditions of the vehicle.

3.3 Traffic Scenarios
Four different traffic conditions were implemented in the simulator. The traffic features concerning the four scenarios are shown in Table 1.

Table 1: Features of traffic scenarios

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Volume [veh/hr]</td>
<td>350</td>
<td>600</td>
<td>800</td>
</tr>
<tr>
<td>Traffic Intensity (N/C)</td>
<td>0.18</td>
<td>0.32</td>
<td>0.42</td>
</tr>
<tr>
<td>Speed of leading vehicle [km/hr]</td>
<td>75</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Speed on opposing lane [km/hr]</td>
<td>85</td>
<td>80</td>
<td>75</td>
</tr>
</tbody>
</table>

The features of the test alignment and the traffic volumes establish a traffic intensity, estimated from traffic volume (N) and capacity of the road (C), ranging between 0.18 and 0.47. These traffic densities correspond to the Level-of-Service A (scenario 1), B (scenarios 2 and 3) and C (scenario 4).

3.4 Procedure
The experiment was carried out using dry pavement conditions in good state of maintenance. The simulated vehicle was a standard medium-class car, both for dimension and for mechanical performance, with automatic gears. The data recording system acquired all the parameters at spatial intervals of 5 m.

The driving procedures were the following: a) communicating to the driver about the duration of the driving and the use of the steering wheel, pedals, and automatic gear; b) training at the driving simulator on a specific alignment for approximately 10 min to allow the driver to become familiar with the simulator’s control instruments; c) the execution of two test scenarios in the established sequence; d) vacating of car by the driver for about 5 min in order to re-establish psychophysical conditions similar to those at the beginning of the test and filling in a form with personal data; e) the execution of the two remaining test scenarios; f) filling in of an evaluation questionnaire about type (nausea, giddiness, daze, fatigue, other) and entity (null, light, medium, and high) of the discomfort perceived during the driving.

The instructions to the drivers were to drive as they would normally. The participants were left free to choose their own headways.

3.5 Participants
Thirty-two drivers (with ages ranging from 22 to 40), male (70%) and female (30%), were selected to perform the driving in the simulator according to the following characteristics: no experience with the driving simulator, at least 3 years of driving experience and an average annual driven distance on rural roads of at least 2500 km. From the analysis of the questionnaire filled in by the drivers, it emerged that no participant experienced any high or medium level of discomfort. Therefore no participant was excluded from sample.
3.6 Data Processing

On the basis of the differences in speed and position between the driver’s vehicle and the other vehicles on the road, the hazardous car-following and passing manoeuvres were identified and the rear-end collision risk and head-on collision risk were evaluated.

In order to assess the risk associated to the car-following situations the two TTC-based risk indicators, TET and TIT, were determined for each driver during the driving on the four traffic scenarios. These parameters were calculated in according to four threshold values of the TTC, that are the most frequently suggested in literature: 2, 2.5, 3 and 4 seconds. The aim of this analysis consisted in identifying the most effective threshold value for assessing actual rear-end collision risk. In other words the aim of this data processing consisted in identifying the TTC-value that produced the least number of false alarms and allowed an exhaustive evaluation of the rear-end collision risk. Subsequently, the average values of the two indicators recorded for 32 drivers on the entire test alignment were quantified (Table 2).

Table 2: TET\text{av} and TIT\text{av} in different traffic conditions and for different threshold values TTC*

<table>
<thead>
<tr>
<th>TTC*</th>
<th>SCENARIO 1</th>
<th>SCENARIO 2</th>
<th>SCENARIO 3</th>
<th>SCENARIO 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TET\text{av} [s]</td>
<td>TIT\text{av} [s²]</td>
<td>TET\text{av} [s]</td>
<td>TIT\text{av} [s²]</td>
</tr>
<tr>
<td>2</td>
<td>0.27</td>
<td>0.06</td>
<td>1.45</td>
<td>0.76</td>
</tr>
<tr>
<td>2.5</td>
<td>1.45</td>
<td>0.46</td>
<td>3.04</td>
<td>1.88</td>
</tr>
<tr>
<td>3</td>
<td>3.58</td>
<td>1.69</td>
<td>5.63</td>
<td>3.99</td>
</tr>
<tr>
<td>4</td>
<td>10.78</td>
<td>8.73</td>
<td>13.94</td>
<td>13.57</td>
</tr>
</tbody>
</table>

Then the indicators were quantified in a similar way as concerns each geometric element (tangents and horizontal curves) of the alignment. Given that the values of such indicators rise as the length of the geometric element increases, the values TET$_{100}$ and TIT$_{100}$ calculated on 100 m of each geometric element of the alignment were determined in order to provide comparable values.

Concerning the head-on collision risk evaluation, for each traffic scenario the following parameters were determined:

a) the number of unsafe passing manoeuvres, identified using a theoretical model based on the comparison between two distances measured at the beginning of the passing manoeuvre: 1) the distance between the driver and the oncoming vehicle and 2) the sum of the distances the two vehicles need to stop. These last distances were determined on the basis of AASHTO hypotheses. The manoeuvre can be considered safe if the distance between the two vehicles is more than the sum of their breaking distances;

b) the average value of the remaining gap to the oncoming vehicle at the end of the passing manoeuvres;

The outcomes of the data processing are reported in table 3.

It should be noted that all the passing manoeuvres were performed along the tangents.

Table 3: The parameters for the evaluation of the head-on collision risk in different traffic conditions

<table>
<thead>
<tr>
<th>Unsafe passing manoeuvres (AASHTO) / total number of passing manoeuvres</th>
<th>SCENARIO 1</th>
<th>SCENARIO 2</th>
<th>SCENARIO 3</th>
<th>SCENARIO 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Remaining Gap [s]</td>
<td>3.44</td>
<td>1.38</td>
<td>0.93</td>
<td>0.98</td>
</tr>
</tbody>
</table>
4 RESULTS AND DISCUSSION

4.1 Driver behaviour in car-following situations

The aim of this section is above all to analyse how the traffic affects driver behaviour in car-following situations and then to investigate the potential influence of geometric road features on driver behaviour in different traffic conditions.

In order to analyze the effects of traffic on driver behaviour during the car-following conditions, the average values $TET_{av}$ and $TIT_{av}$ were related to the corresponding traffic intensity ($N/C$). Figure 3 shows how the two indicators vary with the traffic intensity.

![Figure 3: TET_{av} and TIT_{av} for different traffic intensity values](image)

In both diagrams the relationship between the two variables that gave the value of the coefficient of determination closest to 1 was a quadratic model. That is to say that $TET_{av}$ and $TIT_{av}$ initially increase as traffic intensity increases and then decrease as soon as the maximum value is reached. In particular the maximum value of both indicators is given for a medium-flow traffic condition, close to the one representing the second traffic scenario. Such a traffic condition induces the driver to pass the lead vehicle but at the same time makes carrying out the passing manoeuvre safely difficult. This difficulty is due to the reduced passing gap (it is the time headway between vehicles in the opposing lane) that however is not so small as to induce the driver to definitively give up passing the lead vehicle. Consequently the driver perceives the limited possibility to carry out the passing and keeps short-distance from the lead vehicle, while waiting for passing it. Therefore the driver in such a situation carries out unsafe car-following manoeuvres.

This condition of risk becomes less probable if we consider lower traffic levels. In that case the passing manoeuvre is easier owing to the larger passing gaps on the opposing lane. Therefore the time spent behind the slow vehicle is substantially reduced compared to that spent in the medium-flow traffic condition. Finally for higher traffic levels the very small passing gap precludes the driver from attempting the passing manoeuvre at all; so in most cases the driver renounces the manoeuvre and remains at a due distance from the lead vehicle.

A further note has to be made concerning the increasing dispersion of data shown in figure 3 with the increasing of the threshold value of Time-To-Collision, TTC*. The 4 seconds threshold doesn’t ensure that the identified car-following manoeuvres are actually hazardous.
manoeuvres. In other words the 4 s TTC-threshold seems to be excessively cautious and hence produces false alarms. So a plausible reason for the greater dispersion of data might be the weaker correlation between the car-following manoeuvres (some of which not genuinely risky) and the traffic intensity. On the other hand, the threshold of 2 seconds seems to be too low in order to collect all the truly risky car-following maneuvers. The use of TTC* equal to 2 seconds does not ensure that all the genuinely risky maneuvers are included in the assessment of rear-end collision risk. The threshold of 2 seconds hence makes the exhaustiveness of risk evaluation questionable. For these reasons, TET and TIT values, which were quantified according to 2.5 and 3 s threshold, were analyzed in the following step of the study.

In order to investigate the effects of geometric road features on car-following behaviour, the TET100 and TIT100 values calculated on each geometric element of the alignment for the 2.5 and 3 s threshold were analyzed. An initial analysis of the data showed that in traffic scenarios 1 and 2, the safety indicators (TET100 and TIT100) on tangents assumed values that were almost always different from zero. Instead, on the horizontal curve the safety indicators were prevalently null, showing that these indicators were not influenced by the geometric features of the curves. In traffic scenarios 3 and 4 the indicators were almost always different from zero, on both tangent and curve. Consequently, for the scenarios 1 and 2 the existence of significant correlations between the dependent variables (TET100 and TIT100) on tangents and the independent variables (geometric features and traffic intensity) was investigated. For scenarios 3 and 4, such an analysis was also extended to horizontal curves.

A stepwise multiple linear regression technique was used for model estimation. Concerning the scenarios 1 and 2, significant models of TET100 were found on tangents whose length ranged from 400 m to 1000 m. The best models found gives the values of the parameter as a function of the tangent length (L_t), length of the horizontal curve approaching the tangent (L_ac) and traffic intensity (N/C). For the threshold value TTC* of 2.5 s the model is:

\[
TET100 = 0.101 - 0.202 L_t + 0.080 L_ac + 0.191 N/C, \quad R^2 = 0.891
\]  

(4)

For the TTC-threshold value of 3 s we obtained the following model:

\[
TET100 = 0.216 - 0.395 L_t + 0.205 L_ac + 0.191 N/C, \quad R^2 = 0.914
\]  

(5)

where \(L_t\) and \(L_ac\) are in Km, TET100 is in s/100 m.

The models were significant at the level of 5% and were fully congruent. As a matter of fact, they give us the rear-end collision risk on tangents which: increases as traffic intensity rises, because the traffic interferences increase; decreases as the length of tangent increases, because there are more opportunities to perform an passing manoeuvre on long tangents and avoid a prolonged condition of car-following; increases as the length of the approach horizontal curve increases, probably because the prolonged car-following situation on long curve (where the passing manoeuvre is not usually possible) spurs the driver to put himself on the successive tangent (where the driver perceives the possibility to successfully carry out the passing maneuver), whilst tagging, only a short distance behind the slow vehicle in front of him. It is in such a risky condition that the driver awaits the occasion to be able to carry out the long awaited passing maneuver. No significant models were found for the indicator TIT100.

As regards the scenarios 3 and 4 the analysis was carried out in order to find potential models of TTC-based indicators on both tangent and curve. The analysis did not point to any significant correlations between the TTC-based indicators (TET100 and TIT100) and the geometric features of the test alignment. This result seems to indicate that the influence of the geometric features on the rear-end collision risk tends to be negligible whenever the traffic intensity reaches high levels. In these conditions driver’s behavior is affected exclusively by the interactions among vehicles.
4.2 Driver behaviour in passing situations
The aim of this section is to analyse how the traffic affects the passing behaviour and identify the best model for the evaluation of the head-on collision risk. In order to do this the parameters selected for assessing the risk associated with the passing manoeuvres were related to the corresponding traffic intensity (N/C).

The model based on the comparison between the distance of the driver to the oncoming vehicle and the sum of the distances the two vehicles need to stop, evaluated unsafe all the passing manoeuvres carried out in scenarios 2, 3 and 4 (Table 3). For these manoeuvres the distance between the two vehicles was less than the sum of their breaking distances. However this is a theoretical model that analyses the passing at its beginning and bases on the AASHTO hypotheses for the calculation of the vehicles’ breaking distances. In reality the driver can adjust speed and acceleration during the entire passing phase in relation to the motion condition of the oncoming vehicle. This can be directly observed by speed data collected in the driving simulator and is also in accordance with the outcomes achieved by Jenkins and Rilett (2005) in a previous experiment carried out in a driving simulator. For these reasons the model doesn’t ensure the effectiveness of reproducing the real driver’s behaviour.

Therefore it was considered more appropriate to entrust the evaluation of risk to the remaining gap of the passing driver to the oncoming vehicle that was measured at the end of the passing manoeuvre. This parameter, representing a safety margin at the end of the manoeuvre, allows a global assessment of the driver behaviour during the entire passing phase. Figure 4 shows how the average value of the remaining gap varies with the traffic intensity.

![Figure 4: The average remaining gap for different traffic intensity values](image)

The relationship between the two variables that gave the value of the coefficient of determination closest to 1 was a linear model. In particular the interpolating straight line had a decreasing trend; that is to say the remaining gap decreases as the traffic intensity increases. Therefore it seems to show that for higher traffic intensities the driver performs the passing manoeuvre accepting a greater risk (low values of the remaining gap).

Subsequently a threshold value for the remaining gap equal to 1.5 s was established in order to identify the unsafe passing manoeuvres. For the speeds of the oncoming vehicle and passing vehicle recorded on the four traffic scenarios, 1.5 s determines a gap in terms of distance of about 60 m, that was considered a proper safety margin at the end of the passing manoeuvre.

Figure 5 shows how the ratio between the number of unsafe overtaking (with a remaining gap less than 1.5 s) and the total number of the manoeuvres carried out in each scenario varies with the traffic intensity. Such a ratio rises as traffic intensity increases. The same trend was obtained also for a threshold value of the remaining gap equal to 1 s.
On the basis of these results it is reasonable to state that the accepted risk by drivers increases as the traffic intensity increases. High traffic intensity, causing high vehicle interferences and discomfort during the driving, leads the driver to carry out hazardous passing manoeuvres.

5 CONCLUSIONS

The experimental study at the CRISS driving simulator, aimed at analyzing the driver behavior in car-following and passing situations in different traffic-flow conditions and on different geometric elements of a two-lane rural road, revealed the following main results.

Concerning the car-following situations, the \( TET_{av} \) and \( TIT_{av} \) indicators increase as traffic intensity increases, then decreases as soon as the maximum value is reached. In particular, the maximum values of both indicators are given for a medium traffic-flow condition. This result seems due to the fact that the traffic on the opposing lane is not so high to induce the driver to definitively give up passing the slower lead vehicle. Consequently the driver keeps short-distance from the lead vehicle, while waiting for passing it. During this complex activity the driver adopts unsafe car-following positions.

Concerning the more effective threshold value of TTC, among those suggested in literature for identify genuinely risky car-following maneuvers, the data of TTC-based indicators showed that the value of 4 s seems to be excessively cautious. It could produce false alarms. On the other hand, the threshold of 2 s seems to be too low in order to collect all the effectively risky car-following maneuvers. The use of TTC* equal to 2 s does not ensure that all the genuinely risky maneuvers are included in the evaluation of the rear-end collision risk. The most efficient values of threshold of TTC were considered to be 2.5 and 3 s. This result should be considered for the development of advanced warning information systems to assist the driver in avoiding rear-end crashes.

For these TTC-threshold values, \( TET_{100} \) and \( TIT_{100} \) were calculated on each geometric element of the alignment in order to study the potential relationships between these indicators and the geometric road features. The results were as follows. In traffic scenarios 1 and 2, no significant relationships were found on curves and on short tangents. This results seem to demonstrate that as far as these elements (i.e. curves and short tangents) are concerned, the indicators of rear-end collision risk are not influenced by their geometric features. Significant models of \( TET_{100} \) were found on tangents whose length ranged from 400 to 1000 m. These models could be used to predict the risk associated with car-following manoeuvres on existing two-lane roads or newly designed roads as a function of its geometry and traffic conditions.
Then they could be a useful tool for evaluating rear-end collision risk on the road alignment and developing the most appropriate strategies toward improvements of traffic safety.

In traffic scenarios 3 and 4, which are characterized by higher traffic volumes, no significant models were found for any kind of geometric element. This outcome seems to confirm that the influence of the geometric features on the rear-end risk collision tends to be negligible whenever the traffic intensity reaches high levels. In these conditions the driver’s behavior is affected exclusively by the interactions among vehicles.

As regards the passing manoeuvres, on the basis of the parameters used for the evaluation of the head-on collision risk, it was found that the theoretical model based on the comparison between the distance of the driver to the oncoming vehicle and the sum of their breaking distances, doesn’t ensure the effectiveness of reproducing the real driver’s behaviour. This model analyses the passing at its beginning, without considering that the driver can adjust speed and acceleration during the entire passing phase. Therefore it was considered more appropriate to entrust the evaluation of risk to the remaining gap of the passing driver to the oncoming vehicle at the end of the passing manoeuvre, which allows a global assessment of the driver behaviour during the entire passing phase.

On the basis of this consideration, in order to investigate how the traffic affects the passing behaviour, the average value of the remaining gap and the unsafe passing manoeuvres, characterized by a remaining gap less than a threshold value (1.5 and 1 s), were calculated for each traffic scenario. The outcomes of the analysis show that the accepted risk by driver increases as the traffic intensity increases. High traffic intensity, causing high vehicle interferences and discomfort during the driving, leads the driver to carry out hazardous passing manoeuvres. The effects of the traffic on the driver behaviour should be considered for evaluating and improving the road safety.

REFERENCES
Bella, F. (2009). Can the driving simulators contribute to solving the critical issues in geometric design? In Transportation Research Record: Journal of the Transportation Research Board, No 2138, 120-126.


Hayward, J.C. (1972). *Near miss determination through use of a scale of danger*. Highway Research Record, 384, 24-34


DIFFERENT DESIGNS OF CYCLE TRACKS AND LANES - THE EFFECT ON OBJECTIVE AND SUBJECTIVE SAFETY

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ABSTRACT
Increasing concern about global warming has led to a heightened interest in how to promote more environmentally sustainable transport as cycling. However, the problems are that cyclists run a greater risk of being injured in traffic than car occupants, and that many cyclists feel unsafe. Cycle tracks and lanes are intended to reduce cycle accident risk, and give cyclists increased mobility and feeling of safety. The objective of this study is to find out if and how cycle tracks and lanes should be designed to improve the conditions for cyclists so these measures may contribute to promote cycling in cities.

A comprehensive literature study of effect studies, cycle handbooks and road design manuals from Europe, North America and Australia has been conducted. The effects on accidents of different designs of cycle tracks and lanes are summarised by means of meta-analysis. It is not possible to make a meta-analysis for the effect on subjective safety and mobility. Thus, the assessment is made as a qualitatively summation of the included studies and a theoretical assessment of the effect.

Cycle lanes reduce the number of cycle accident along the road and in intersections. Cycle tracks do not have the same positive effect on cycle safety. It seems that cycle tracks transfer cycle accidents from along the road to intersections. However, not all designs of cycle tracks in intersections have a negative effect on safety. The subjective feeling of safety usually increases among cyclists when cycle traffic is physically separated from motorized traffic. In intersections measures that contribute to an increased mix of cycle and motorized traffic are likely to make cyclists feel more unsafe. Mobility is improved for many but not all measures.

The conclusion of the study is that building of cycle tracks is recommended as a measure to improve the condition for cyclists, because it is possible to eliminate the negative effect on safety by making a proper design in intersections. In addition, cycle tracks, together with other measures, may increase the number of cyclists that may improve safety because the cyclists become more visible.

1 INTRODUCTION
Increasing concern about global warming has in most countries lead to a heightened interest in how to promote more environmentally sustainable transport as cycling. However, the problem with cycling is that cyclists run a great risk of being injured in traffic.

2644 cyclists were killed in road accidents in 23 European countries in 2008. These fatalities make up 7 % of the total number of road accident fatalities in these countries. The percentage varies between 1.4 % in Greece and 20.7 % in Nederland (EU, 2009).

An estimate based on official accident statistics and the national household travel survey in Norway (Bjørnskau, 2008) shows that the accident rate for cyclists is 5-6 times higher per km travelled than for drivers and passengers in cars.

The real accident rate for cyclists is most likely even higher. A Norwegian study (Bjørnskau, 2005) showed that there are 7-8 cycle accidents for each cycle accident that is
reported in official accident statistics. Car accidents are also underreported, but to a lesser
degree. When underreporting of cycle and car accidents in official accident statistics is taken
into account, the accident rate for cyclists is ca. 20 times that of car occupants.

Another problem with cycling is that many cyclists do not feel safe in traffic, especially
when they are travelling in mixed traffic on roads with heavy car traffic (Sørensen and
Mosslemi, 2009). According to Bjornskau (2004) 28 % of all cyclists feel unsafe, and
according to Backer-Grøndahl et al. (2007) the percentage of cyclists feeling unsafe is 19 %.
Only among motorcyclists and partly car drivers there is a larger proportion feeling unsafe.

Cycle tracks and cycle lanes are intended to make it more attractive to ride your cycle. The
intension with these measures is to separate cycle traffic and motor vehicle traffic more or less
physically. The purpose is to reduce cycle accident risk and give cyclists increased mobility
and feeling of safety when travelling in public traffic areas.

However, the question is if these measures fulfil all three purposes simultaneously, or how
the cycle infrastructure should be planned and constructed to do so?

2 OBJECTIVE
The objective of this study is to estimate the effect of different designs of cycle tracks and
cycle lanes on objective safety, subjective safety and partly mobility on road sections and in
intersections in urban areas.

In other words, the objective is to find out if and how cycle tracks and lanes should be
designed to improve the conditions for cyclists so these measures may contribute to promote
cycling in cities.

This paper is based on the work in three projects: 1) Updating of the chapter about the
safety effect of cycle tracks and cycle lanes in “The handbook of road safety measures”
(Elvik, Høye, Sørensen and Vaa, 2009), 2) a project about how intersections in cities should
be designed to secure environment friendly transportation (Sørensen, 2009) and 3) a project
where the effect of 125 road safety measures on subjective safety among vulnerable road
users have been summarised (Sørensen and Mosslemi, 2009).

This paper only focuses on the effect for cyclists. The effects for pedestrians and car
drivers are not described. For information about that it is referred to the three listed reports.

3 DESCRIPTION OF THE MEASURES
A distinction is made between the following cycling facilities which represent varying
degrees of separation from motor vehicle traffic:

- **Cycle lanes**: Protected space on the carriageway, separated from motor traffic by means
  of road markings, and often additionally announced by road signs.
- **Cycle tracks (cycle paths)**: Space that is physically separated from the carriageway, e.g.
  by kerbstones, lawn or a ditch.
- **Tracks for walking and cycling**: Roads for pedestrians and cyclists travelling in both
  traffic directions, which are physically separated from the carriageway, tracks for
  walking and cycling are usually constructed on one side of the road only.

At intersections, cycle tracks and cycle lanes can be designed in numerous ways (Sørensen,
2009). 12 of the most common designs have been investigated in this study:

- **Interrupted cycle track**: The cycle track ends immediately before the intersection. In the
  intersection there is either a marked cycle lane or no separate cycle facility.
- **Continuing cycle track**: The cycle track continues in yield intersection.
- **Advanced stop line**: Advanced stop line arrangements comprise a stop line for motor
  vehicles and an additional stop line for cyclists nearer the signal heads.
− **Cycle box:** In front of the stop line for motor vehicles at signalised intersections, there is in a reservoir for waiting cyclists to occupy.

− **Coloured cycle lane:** In the intersection the cycle lane is painted for the whole width of the cycle lane (e.g. in blue, green or red), and additionally marked with cycle symbols.

− **Other types of road markings:** Other types of road markings for cyclists in yield intersection includes different pattern as harlequin and different cycle symbols.

− **Bent-out cycle track crossing:** On a bent-out crossing, the cycle track approaches are deflected away from the main carriageway to create a gap of one or two car lengths between the main road and the crossing.

− **Bent-in cycle track crossing:** In contrast to a bent-out cycle track crossing, the cycle track approaches are deflected towards the main carriageway.

− **Central approach lane:** Exclusive cycle lane at signalised intersections to the left for the motor vehicle right turn lanes for straight forward cycling.

− **Right side approach lane:** Exclusive cycle lane at signalised intersections to the right for the motor vehicle right turn lanes for cyclists to turn right.

− **Left side approach lane:** Exclusive cycle lane at signalised intersections to the left for the motor vehicle lanes for cyclists to turn left.

− **Right turn cycle tracks:** Exclusive right turn cycle tracks outside the intersection.

### 4 METHOD

#### 4.1 Literature study

A comprehensive literature study of 46 evaluation studies, 22 cycle handbooks and 18 road design manuals from primarily Europe, USA, Canada and Australia has been conducted.

The purpose of the literature study was to collect 1) all recommendations about how cycle tracks and cycle lanes should be designed to secure good conditions for cyclists and 2) all relevant effect studies concerning the effects of each different cycle infrastructure design on objective safety, subjective safety and mobility.

The studies have been gathered by means of a systematic literature search consisting of a fixed and a variable part. The fixed part is a comprehensive search in a sample of sources:

− Bibliographical databases as Science Direct, ISI web of Science and Worldcat
− The library of the Institute of Transport Economics
− Scandinavian journals and proceedings from selected international conferences
− Reports issued by selected research institutes
− Cycle handbooks and road design manuals from public road administrations.

The literature search was conducted using a variation of different key words, i.e. cycle, bike, cyclist, track, lane, path, safety, accident, subjective and perceived safety and mobility.

The variable part of the literature search comprises references found in the reference lists in the studies which were retrieved in the fixed part of the search.

#### 4.2 Meta-analysis

The effects on accidents and injuries of different designs of cycle tracks and lanes are summarised by means of meta-analysis, provided it is applicable. Meta-analysis is a quantified synthesis of results of several studies that have evaluated the same measure, stated in the form of a weighted mean estimate of effect.
There are a number of textbooks (Elvik et al., 2009) on meta-analysis that describe various techniques in detail. Here, only the main elements are described.

The study unit in a meta-analysis is an estimate of effect. An estimate of effect has to be stated as a precise numerical estimate in order to be included in the meta-analysis. Moreover, the number of accidents on which the estimate of effect is based on or the standard error of the estimate has to be known to make it possible to weight the result according to its statistical precision. This means that some of the 46 found studies in the literature search not qualifies to be included in the actual meta-analysis. In chapter 5 it is described which studies that is included in the effect estimation for each measure.

A single study may contain more than one result. In such cases, all results, or the most important results, have been included in the meta-analysis.

For each study result the effect estimate and the statistical weight are summarized or calculated. Estimates of effect are calculated as odds ratios. Most of the included studies are before and after effect studies with control groups. For these types of studies odds ratio is calculated as:

\[ \text{Effect estimate} = \frac{A/B}{C/D}, \]

where

- \( A/B \): Number of accidents in test group, after/before
- \( C/D \): Number of accidents in control group, after/before

The statistical weights are calculated in different ways for different study designs, but the weights always depend on the number of accidents in the study. The more accidents in the study, the more precise the effect estimate are expected to be and the higher weight is assigned to the effect estimate.

There are two methods of combining estimates of effect, the fixed effects model and the random effects model. In this study the first model is used. In this model the statistical weights are estimated as the inverse of the variance of the natural logarithm of each effect estimate. This means that the result gets a higher weight the smaller the variance is. The weighted summary effect based on a set of \( g \) estimates is calculated as formula 1. A 95 % confidence interval for the weighted mean effect is obtained according to formula 2.

1) \[ \text{Weighted summary effect} = \exp \left( \frac{\sum_{i=1}^{g} V_i \cdot \text{LN(effect estimate)}_i}{\sum_{i=1}^{g} V_i} \right) \]

2) 95 % confidence interval = \[ \exp \left[ \frac{\sum_{i=1}^{g} V_i Y_i / \sum_{i=1}^{g} V_i}{\sum_{i=1}^{k} V_i} \right] \pm 1.96 \cdot 1/ \sqrt{\sum_{i=1}^{k} V_i} \], where

Exp: The exponential function
V: Statistical weight for the effect estimates i to g
LN: The natural logarithm
Y: The logarithm of each estimate of effect.

4.3 Theoretical and qualitative assessment
Regarding the effect on subjective safety, mobility and for some measures objective safety, it is not possible to make a meta-analysis. Thus, the assessment is made as a qualitatively summation of the results of the included studies.

Additional, a method for theoretical assessment of the effect on subjective safety have been developed by Sørensen and Mosslemi (2009) and conducted for each variant of the design of
tracks or lanes. 16 different factors having impact on subjective safety have been identified. For each measure it is assessed if the measures have positive or negative effect on each of the 16 factors, as well as whether the effect are large, medium or small. The 16 factors and their importance are listed in table 1.

Table 1: Factors influencing subjective safety of cyclists (Sørensen and Mosslemi, 2009).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic volume</td>
<td>More traffic → more unsafety</td>
</tr>
<tr>
<td>Speed</td>
<td>Higher speed → more unsafety</td>
</tr>
<tr>
<td>Heavy vehicle</td>
<td>More heavy vehicle → more unsafety</td>
</tr>
<tr>
<td>Thoughtfulness</td>
<td>More thoughtfulness from drivers → less unsafety</td>
</tr>
<tr>
<td>width of lanes and shoulders</td>
<td>More distance between vehicles and cyclist → less unsafety</td>
</tr>
<tr>
<td>Crossing distance</td>
<td>Less crossing distance → less unsafety</td>
</tr>
<tr>
<td>Cyclists</td>
<td>More cyclists → less unsafety</td>
</tr>
<tr>
<td>Cycle tracks</td>
<td>Cycle tracks → less unsafety</td>
</tr>
<tr>
<td>Separation/integration</td>
<td>Separation → less unsafety</td>
</tr>
<tr>
<td>Design of intersections</td>
<td>3-leg and 4-leg intersection → more unsafety</td>
</tr>
<tr>
<td>Number of crossings</td>
<td>More crossings → more unsafety</td>
</tr>
<tr>
<td>Road conditions</td>
<td>Slippery, icy and holes → more unsafety</td>
</tr>
<tr>
<td>Sight conditions</td>
<td>More sight → less unsafety</td>
</tr>
<tr>
<td>Road light</td>
<td>More light → less unsafety at night</td>
</tr>
<tr>
<td>Skills</td>
<td>More skills → less unsafety</td>
</tr>
<tr>
<td>Personally protection</td>
<td>More protection equipment → less unsafety</td>
</tr>
</tbody>
</table>

5 RESULTS

5.1 Effect on cycle safety for road sections

Table 2 summarises the safety effect of cycle tracks, cycle lanes and tracks for cycling and walking along road sections on cycle injury accidents.


On road sections with cycle lanes there are 19% fewer cycle injury accidents than on roads without cycle lanes. However, the reduction is not significant. On road sections with cycle tracks there is a smaller but significant reduction on 11%. Severity of the accident has not been examined in the included studies.
Most of the studies have not controlled for the number of cyclists, i.e. the results refer to changes in the total numbers of accidents after cycle tracks or cycle lanes were installed, compared to before the installation.

The total number of cycle accidents seems to be unaffected by building of tracks for cycling and walking. However, a number of the included studies have found that the measure increase cycling traffic. In other words, the accident rate seems to decrease.

Table 2. The effect of cycle lanes, cycle tracks and tracks for cycling and walking along road sections on objective safety, subjective safety and mobility.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Objective safety (Percentage change in the number of cycle injury accidents)</th>
<th>Subjective safety (Change in percentage feeling unsafe)</th>
<th>Mobility (Change in speed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle lane</td>
<td>-19 (-36; +3)</td>
<td>-20-75</td>
<td>+0-4</td>
</tr>
<tr>
<td>Cycle track</td>
<td>-11 (-18; -3)</td>
<td>-18-50</td>
<td>Positive</td>
</tr>
<tr>
<td>Track for cycling and walking</td>
<td>+2 (-42; +78)</td>
<td>Positive</td>
<td>Positive / negative</td>
</tr>
</tbody>
</table>

5.2 Effect on cycle safety in intersections
Table 3 summarises the safety effect of different designs of cycle tracks, cycle lanes and tracks for cycling and walking in intersections.

Table 3. The effect of different designs of cycle lanes, cycle tracks and tracks for walking and cycling in intersections on objective safety, subjective safety and mobility. Positive effect means that the measure probably reduces the number of cycle accidents or cyclists feeling unsafe or increases the speed of the cyclists.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Objective safety (Percentage change in the number of cycle injury accidents)</th>
<th>Subjective safety (Change in percentage feeling unsafe)</th>
<th>Mobility (Change in speed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle lane, normal design</td>
<td>-25 (-35; -13)</td>
<td>Less positive than cycle tracks</td>
<td></td>
</tr>
<tr>
<td>Cycle lane, normal design, signalised intersections</td>
<td>-9 (-29; +16)</td>
<td>Less positive than cycle tracks</td>
<td></td>
</tr>
<tr>
<td>Cycle track, normal design</td>
<td>+24 (+11; +38)</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Cycling and walking track, normal design</td>
<td>+1 (-37; +62)</td>
<td>Depends of design</td>
<td></td>
</tr>
<tr>
<td>Interrupted cycle track</td>
<td>-31 (-45; -12)</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Continuing cycle track</td>
<td>-13 (-36; +16)</td>
<td>Positive</td>
<td>Positive</td>
</tr>
<tr>
<td>Advanced stop line</td>
<td>-19 (-47; +23)</td>
<td>Positive / negative (Positive)</td>
<td></td>
</tr>
<tr>
<td>Cycle box</td>
<td>Positive</td>
<td>Positive / negative (Positive)</td>
<td></td>
</tr>
<tr>
<td>Coloured cycle lane</td>
<td>-22 (-33; -8)</td>
<td>Positive</td>
<td>None</td>
</tr>
<tr>
<td>Other types of road markings</td>
<td>-6 (-31; +29)</td>
<td>Positive</td>
<td>None</td>
</tr>
<tr>
<td>Bent-out cycle track crossing</td>
<td>Positive</td>
<td>Positive</td>
<td>Negative</td>
</tr>
<tr>
<td>Bent-in cycle track crossing</td>
<td>Positive</td>
<td>Negative</td>
<td>Negative</td>
</tr>
<tr>
<td>Central approach lane</td>
<td>(Positive)</td>
<td>Negative</td>
<td>None (positive)</td>
</tr>
<tr>
<td>Right side approach lane</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Positive</td>
</tr>
<tr>
<td>Left side approach lane</td>
<td>(Negative)</td>
<td>Negative</td>
<td>Positive</td>
</tr>
<tr>
<td>Right turn cycle track</td>
<td>Positive / negative</td>
<td>Positive</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Besides the already listed references under the previous chapter the results about the safety effect in intersections are based on 11 other studies from Denmark, Sweden and United Kingdom (Berggrein and Bach, 2007, Gårder, Leden and Pulkkinen, 1998, Jensen and

In intersections with “normal” cycle lanes there are significant fewer cycle accidents than if there is no cycle lane. Contrary to cycle lanes, cycle tracks do not seem to improve safety in intersections, but only on road sections. It seems that cycle accidents are transferred from along the road to intersections. In total, cycle tracks increase the number of cycle accidents with 7 % (-3; +18). A possible explanation for the increase at intersections is that the physical separation of cycle and motor traffic makes cyclists and drivers pay less attention to each other. At the same time, cyclists may be tempted to overestimate their own safety. A lack of attention is a problem at intersections where cyclists and drivers have to interact (Agerholm et al., 2008, Jensen, 2006).

For the 12 “special” designs of cycle tracks and lanes in intersections good evaluations have only been found for five of them. In addition, there are only few and small evaluation studies for these designs. Thus, the results are very uncertain. For the seven other designs more qualitative assessments about the safety effect have been made (Sørensen, 2009).

Interrupted cycle track was found to significantly reduce the number of cycle accidents. A likely explanation is that cyclists and drivers pay more attention to each other in mixed or partly mixed traffic, and that cyclists are feeling more unsafe (Agerholm et al., 2008).

A non-significant reduction of cycle accidents was found for continuing cycle track. According to a Danish study not included in the meta-analysis, the accident rate for cyclists is 26 % lower at intersections with continuing cycle tracks than at intersections with interrupted cycle tracks, and the number of killed or seriously injured cyclists is higher at intersections with continuing cycle tracks (Fjordback et al., 2007).

Advanced stop lines were found to reduce cycle accident numbers, although the effects are not significant. The measure makes cyclists more visible to drivers and prevents vehicles turning right from colliding with cyclists cycling straight ahead.

The objective with cycle boxes is the same as for advanced stop lines. Additionally, the measures may have a speed reducing effect on vehicle traffic. The reviewed cycle handbooks recommend the measure and describe that it has a positive effect on cycle safety (Sørensen, 2009). No studies about the effect on cycle accidents have been founded. However, conflicts and behaviour have been studied in several projects (Anderson and Lund, 2009, Atkins, 2005, Hunter, 2000, Newman, 2002, Ryley, 1996). They conclude that cycle boxes have a positive effect on safety. Hunter (2000) finds for example that that cyclists who used the cycle box correctly, were not involved in conflicts with motor vehicles. However, only 22 % of all cyclists used the cycle box, for the most part because cars stopped at the cycle box, not at the stop line intended for motor vehicles. About 50 % of all cars did so. Anderson and Lund (2009) found similar result. A possible explanation is that drivers do not want to have cyclists in front of them because it reduces their mobility (Newman, 2002).

A significant reduction of cycle accidents was found at intersections with coloured cycle lanes. Coloured cycle lanes are recommended in many countries, especially in complex intersections (Sørensen, 2009). However, results from a Danish study (Jensen, 2008) indicate that coloured cycle lanes are most favourable in non-complex intersections, and may have detrimental effects in complex intersections.

Other types of road markings in yield intersections were also found to reduce the number of cycle accidents. The results are however not significant.

Only one evaluation study about bent-out cycle track crossing was found (Andersen, Nielsen and Olesen, 2004). This study is based on too few accidents to draw any conclusions about the safety effects of this measure. However, several of the reviewed handbooks recommend the measure because it reduces the numbers of conflicts between cyclists and motor vehicles. The measure gives drivers turning into the side road extra time to notice
crossing cyclists, and allows vehicles waiting to exit the side road to do so without blocking the crossing point.

No evaluations of the effects on cycle accidents have been found for bent-in cycle track crossing. The objective is to make cyclists more visible to drivers, so the intention with the measure is to improve safety.

Central, right side and left side approach lanes are recommended in a number of countries (Sørensen, 2009) and have been used over many years, e.g. in Denmark. All the same, the safety effects have only been evaluated indirectly or in small studies. None of the studies have reached clear conclusions as to whether or not accidents or conflicts between cyclists and motor vehicles are reduced (City of Portland, 1999, Hunter, 2000a, Hunter et al., 2000, Nielsen, 1995, Ryley, 1996).

Andersen, Nielsen and Olesen (2004) have made an evaluation of right turn cycle tracks, but the study does not make it possible to draw any conclusions about the safety effects. According to the reviewed handbooks the measure reduces the number of conflicts between cyclists and motor vehicles but increases the number of conflicts between cyclists and pedestrians (Sørensen, 2009).

5.3 Effect on subjective safety for cyclists
Subjective feeling of safety usually increases among cyclists when cycle traffic is physically separated from motorized traffic. According to different surveys cycle tracks increase the number of cyclists feeling safe with 20-75%. Cycle lanes also increase the subjective feeling of safety, but to a lesser degree than cycle tracks (Backer-Grøndahl et al., 2007, Jensen, 2006b, 2006c, Nilsson, 2003, Statens vegvesen, 2003, Vejdirektoratet, 2000).

No studies about the effect of different designs of cycle tracks and lanes in intersections on subjective safety have been founded. Thus, the assessment is based on descriptions in handbooks and the developed method for theoretical assessment (Sørensen and Mosslemi, 2009).

In intersections, measures that separate cycle and motorized traffic are likely to increase the subjective feeling of safety, i.e. continuing cycle track, coloured cycle lane, other types of road markings, bent-out cycle track and right turn cycle track (Sørensen, 2009).

Measures that contribute to an increased mix of cycle and motorized traffic on the other hand, are likely to make cyclists feel more unsafe, i.e. interrupted cycle track, bent-in cycle track, and central and left side approach lane.

Advanced stop line and cycle box for cyclists may increase the feeling of safety for cyclists because they become more visible. On the other hand, cyclists may also feel pressured from vehicles waiting behind them (Sørensen, 2009).

5.4 Effect on mobility for cyclists
The effects of different designs of cycle infrastructure on mobility for cyclists are even less studied than the effect on subjective safety. There are more studies about the effect on driving speeds for cars as for example (Bolling, 2000, Fowler, 2005, Nilsson, 2001, Wittink, 2003).

Cycle tracks, cycle lanes and tracks for cycling and walking may improve mobility for cyclists. It is found that the amount of cycling increases when cycle tracks and lanes are built (Elvik et al., 2009). This represents an improvement in mobility for cyclists. Cycle tracks and tracks for walking and cycling improve mobility for cyclists when they are built to minimise the travel distance for cyclists. In other cases, the travel distance is increased. Cycle tracks were found to increase average speed among cyclists with 0-4 km/h (Nilsson, 2000).

At intersections several of the designs probably have a small positive effect on mobility. These are; Left and right side approach lane, right turn cycle track, continuing cycle track and partly advanced stop line and cycle box (Sørensen, 2009).
**Left side approach lanes** replace a large left turn in two stages with one small and more directly left turn in one stage. **Right side approach lanes** improve mobility because cyclists cycling straight forward and cyclists turning right do not block for each other. It also offers the opportunity for cyclists turning right to have their own face in the signal regulation or to cycle for red light. **Right turn cycle tracks** outside the intersection make it possible to turn right when the light is red, and it also gives a more direct route.

**Advanced stop lines** and **cycle boxes** are found to improve mobility for cyclists, because cyclists are in front of the motor vehicles. However, many drivers do not stop at their stop line, but drive into the area reserved for cyclists (Hunter, 2000, Newman, 2002). Cycle tracks that are **interrupted, bent in or bent out** are most likely to reduce speed for cyclists (Sørensen, 2009). **Interrupted cycle tracks** may lead to vehicles blocking the way for cyclists. This problem may be reduced by a marked cycle lane in the intersection. **Bent-in or bent-out cycle tracks** force cyclists to slow down and eventually to stop. At the same time the cycle route is a bit longer.

**6 DISSUSSION**

The study reveals six dilemmas that immediately make it difficult to answer the question about how cycle tracks and lanes should be designed to improve the conditions for cyclists.

**Dilemma 1.** The objective of cycle infrastructure measures is either to improve objective safety, subjective safety or mobility for cyclists, and few of the measures have positive effect on all three parameters at the same time. Thus, it may be necessary to prioritize between the three motives.

**Dilemma 2.** What is the most important condition to improve for cyclists? One may argue that it is more important to “arrive alive” than feel safe and have high mobility. However, subjective safety and mobility is noticeable among cyclists while the real risk for accidents is not. Improved mobility and feeling of safety may therefore be assessed as an improvement, while lower objective risk for cycle accidents may have the opposite effect.

**Dilemma 3.** Different types of cyclists have different preferences. For “strong” cyclists mobility may be more important than the feeling of safety, and for more “weak” cyclists as children and elderly subjective safety may be more important than high mobility.

**Dilemma 4.** Different effect of measures in the short run and in the longer term. Some measures may have a negative effect on for example safety in the short run as for example cycle tracks, but this may change in the longer term when several cycle tracks have been built. Other measures, e.g. coloured cycle lanes immediately have a positive effect, but if all cycle lanes are coloured the effect will probably decline.

**Dilemma 5.** Difference in expected and reel effect. Cycle tracks may for example be expected to have a positive effect on cycle safety, but effect studies show that the reel effect in the short run is negative. This is a great problem because for several of the measures only few, small or poor effect studies have been conducted. These studies often only evaluate the effect on safety and not subjective safety and mobility. Thus, we know very little about the “reel” effect on mobility and the felling of safety.

**Dilemma 6.** The effect of a measure may differ from country to country because of different traffic and cycle culture. The found effects do not necessary apply for all countries.

**7 CONCLUSION**

To promote cycling in cities and overcome the described dilemmas the following four recommendations are made.

**Recommendation 1.** It is not a question if cycle tracks should be built or not to improve the conditions for cyclists, but a question about building them in the right way. If different designs are combined it is possible to maximise the advantage and minimise the disadvantage.
For example the negative effect of cycle tracks on safety in intersections may be minimised or eliminated if one of the intersection designs of cycle tracks with positive effect are used.

**Recommendation 2.** Many and connected cycle tracks and lanes in stead of isolated measures are likely to increase the number of cyclists. Even though some of these measures in the short run have a negative effect on safety the total package has a positive effect because cyclists become more visible. Car drivers are therefore paying more attention to the cyclists.

**Recommendation 3.** A separate cycle road network with high mobility for “strong” cyclists respectively a separate cycle road network with high subjective safety for “weak” cyclists should be considered.

**Recommendation 4.** More effect studies are necessary for more of the different designs of cycle tracks and lanes in intersections to make to possible to assess the effect. These studies should include both the effect on safety, subjective safety and mobility.

**REFERENCES**


972
Publications 55. Espoo, The Technical Research Centre of Finland.
Metodik för före-/efterstudier. Tillämpat på cyklister trafiksäkerhet. KFB Rapport 15.
11 cykelbanor i Malmö. Malmö, Gatukontoret, Trafikdivisionen.
Newman, A. (2002). The marking of advanced cycle lanes and advanced stop boxes at
signalised intersections, Christchurch City Council, Christchurch.
Nielsen, E. D., Andersen, K. V. and Lei, K. M. (1996). Trafiksikkerhedseffekten af cykel-
Management and Road Safety, held at PTRC Summer Annual Meeting, 1994, 113-123.
Nilsson, A. (2001). Re-allocating road space for motor vehicles to bicycles: effects on
cyclist’s opinion and motor vehicle speed, The AET European Transport Conference.
975. Crowthorne, Berkshire, Transport and Road Research Laboratory.
and signal timings, TRL report 181, Transport Research Laboratory, Berkshire.
Högskolan i i Lund, Institutionen för trafikteknik.
Record, 1168, 49-56.
Statens vegvesen (2003). Sykkelhåndboka – Utforming av sykkelanlegg, Veiledning,
Håndbok 233, Statens vegvesen, Oslo.
sykkelveger. Oslo, Asplan Samferdsel.
Sørensen, M. (2009). Kryssløsninger i by – internasjonale anbefalinger for å sikre
miljøvennlige transport, report 1004, Institute of Transport Economics, Oslo.
safety measures on subjective safety among vulnerable road users, report 1009, TOI, Oslo.
Institutt for Samferdselsteknikk. Trondheim, Norges Tekniske Høgskole.
bebouwde kom II. Rapport R-85-46, SWOV, Leidschendam.
cyclists. Traffic Engineering and Control, 34, 54-60.
London. Traffic Engineering and Control, 28, 628-635.
Wittink, R. (2001). Promoting of mobility and safety of vulnerable road users, D-2001-3,
Institute for Road Safety Research (SWOV), Leidschendam, Nederland.
Norges Tekniske Høgskole, Trondheim, Institutt for samferdselsteknikk.
A NEW METHODOLOGY FOR IMPLEMENTING ROAD DESIGN GUIDELINES IN THAILAND

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ABSTRACT

In the past decades several successful road traffic safety measures were implemented to improve road safety situation in various countries around the world based on international technology and knowledge transfer.

A new methodology for design guideline implementation based on international technology and knowledge transfer will be described in this paper. The objective of the proposed methodology is to foster the development and implementation of design guidelines for road infrastructure in emerging and developing countries – and here especially in Thailand. The transfer and adaptation of proven design methods and technologies is proposed as an appropriate measure to close existing gaps of knowledge and help to improve road traffic safety in these countries in an efficient way.

The paper was prepared by the partners of the international network “NICE on RoadS – EU-Asia Network In Competence Enhancement on Road Safety” with financial support from the European Commission.
1. INTRODUCTION

Road traffic accidents are a trans-boundary problem affecting European as well as Asian countries. The socio-economic cost of road accidents with immense human suffering is far too high a price to pay for mobility. Around the world, national and international organisations have set the reduction of the number and the severity of road accidents as one of their major transport policies.

For instance in 2001 the European Commission declared in the White Paper “European transport policy for 2010: time to decide” the ambitious objective to reduce the number of fatalities on roads by half by 2010. Also several Asian countries proclaimed similar objectives in their countries. For instance in Thailand the Thailand Road Safety Manifesto (TROSAMAN) proclaimed the goal to substantially reduce the number of road deaths by setting the objective of saving 5,000 lives in 5 years.

“For the past five years, 2002-2006, some 66,300 people died in road traffic accidents in Thailand or an average of 13,260 deaths per annum. Some 5,0 million people were injured, some of them severely. The economic loss resulted from traffic accidents were estimated at 232,000 million Baht, corresponding to approximately 2.81% of the country’s Gross National Product” (Thailand Road Safety Manifesto, 2007).

In 2009, the Thai government has adopted a similar target to those proclaimed by the UN Road Safety Collaboration which called for 50% reduction in number of fatalities worldwide by 2020.

The World Health Organisation (WHO, 2004) pointed out the need for activities to counteract the current situation, otherwise “without increased efforts and new initiatives, the total number of road traffic deaths worldwide and injuries is forecast to rise by some 65% between 2000 and 2020, and in low-income and middle-income countries deaths are expected by as much as 80%”.

In response to this problem the WHO (2004) has recommended that “in developing countries, …, the priority should be the import and adaptation of proven and promising methods from developed nations, and a pooling of information as to their effectiveness among other low-income countries”.

Following this recommendation, a new approach for design guideline implementation based on international technology and knowledge transfer” will be described in this paper. This approach, which is - as far as the authors know - the first of its kind being carried out in Thailand in the area of road design, gives an overview of working steps and important aspects which should be considered for an efficient technology and knowledge transfer in order to effectively improve road traffic safety.

This paper was prepared by the partners of the international network “NICE on RoadS” in the framework of the Thai-E.C. project “Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai Universities” with financial support from the European Commission (www.nice-roads.com).

2. INFLUENCING ELEMENTS - AREAS OF ROAD SAFETY ACTIONS

A study originally published by Treat (1977) revealed that the influencing elements HUMAN, VEHICLE and ENVIRONMENT are to be blamed for the occurrence of accidents. Following this approach a traffic accident is a result of the failure of at least one of these elements as shown in Figure 1a.
A lot of influencing variables can be assigned to the influencing elements, for instance: Element 1: “HUMAN” includes the behaviour of the drivers and other road users; Element 2: “VEHICLE” includes e.g. the intrinsic safety of the vehicles with the view on technical aspects; Element 3: “ENVIRONMENT” includes amongst others the intrinsic safety of roads and environment with the view on the design of road infrastructure.

Furthermore one can distinguish between three action areas which comprise measures to address road traffic safety problems - also known as “Triple-E Model” (see Figure 1b).

The first “E” (Education) comprises different education related measures to improve road safety like e.g. training courses for drivers or children. The second “E” (Enforcement) comprises measures which punish road users if they do not follow official rules and regulations in road traffic like for instance drunken driving or exceeding speed limits. The third “E” (Engineering) deals with measures relating to engineering aspects, here for instance with the design of road infrastructure which have, beside other sub-areas of engineering (e.g. design of vehicles, etc.) a significant influence on road traffic safety.

3. EFFICIENT ROAD SAFETY MEASURES
In the last decades different road safety measures were implemented in European countries to improve road safety. These road safety measures addressed all influencing elements and action areas as mentioned above.

The trend in fatalities in road traffic accidents in Germany is shown in Figure 2 as an example during the period 1953 to 2008. Some selected road safety measures and the respective points of introduction are marked in this figure. Measures like the introduction of speed limits, maximum blood alcohol limits, obligatory use of helmets and seat belts contributed to improved road traffic safety. Of course, beside the measures mentioned, other aspects like e.g. the technical development of vehicles and developments in the design of road infrastructure had also a strong influence on road traffic safety. Nevertheless it is estimated that the above mentioned measures had a significant influence on the decrease of the number of fatalities in road traffic accidents in Germany.
Furthermore various road traffic safety measures and methods were successfully implemented related to the influencing-element “ENVIRONMENT” and the action-area “Engineering” in Germany in the last decades. In a series of cases the new measures and methods were the result of international technology and knowledge transfer, like e.g. the implementation of Road Safety Audits in the planning process of roads. Here German experts took comprehensive experiences from other countries around the world, e.g. European countries and Australia, into consideration in the preparation process of their national guidelines.

Another impressive example is the introduction of the compact one-lane roundabout as a new intersection type in Germany about two decades ago. Good experiences gained from this intersection type in several countries, e.g. France and the United Kingdom were the main
reason why this intersection type was introduced in Germany. Nowadays an estimated 3000 to 5000 compact one-lane roundabouts are in operation in Germany (Brilon, 2008). Several comparison and before-after studies came to the conclusion that compact one-lane roundabouts can serve traffic volumes with a high safety level. For this reason the application of this intersection type is acknowledged as an appropriate measure for redesign of existing intersections (see Figure 3) and for the design of new intersections in the road network.

Similar experiences were also obtained with roundabouts in various countries around the world as shown in Table 1 (FHWA, 2000).

**Table 1:** Mean crash reductions by re-design of intersections into roundabouts

Source: FHWA (2000)

<table>
<thead>
<tr>
<th>Country</th>
<th>All Crashes</th>
<th>Injury Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>41 - 61%</td>
<td>45 - 87%</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>57 - 78%</td>
</tr>
<tr>
<td>Germany</td>
<td>36%</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>47%</td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td></td>
<td>25 - 39%</td>
</tr>
<tr>
<td>United States</td>
<td>37%</td>
<td>51%</td>
</tr>
</tbody>
</table>

Figures shown in Table 1 give a clear example to the fact that the implementation of similar design approaches in different countries can be an effective measure to improve road traffic safety in these countries around the world. Efficient transfer of technologies and related knowledge between international and national organisations and institutions can be considered as the basis to foster the process of implementation and diffusion of successful design methods of road infrastructure.

Further examples of successful design methods and measures and their impact on road traffic safety are explained by provision of comprehensive comparison studies by Elvik et al. (2009).

### 4. TECHNOLOGY AND KNOWLEDGE TRANSFER

#### 4.1 Context

The WHO (2004) recommended technology and knowledge transfer as an appropriate way to improve road traffic safety: “in developing countries, …. the priority should be the import and adaptation of proven and promising methods from developed nations, and a pooling of information as to their effectiveness among other low-income countries”. This statement can also be applied to emerging countries like Thailand.

Following this recommendation different road safety manuals were published in the last years e.g. by World Health Organisation (WHO), Global Road Safety Partnership (GRSP), PIARC World Road Association and FIA Foundation (FIA) in order to foster the implementation of
successful road safety measures (cf. Figure 2) like:

- wearing helmets (WHO, 2006),
- counteracting drinking and driving (GRSP, 2007),
- introducing road safety audits (PIARC, 2007),
- introducing speed management (GRSP, 2008),
- and considering seat-belt use and child restraints (FIA, 2009).

Furthermore several guidelines for the design of road infrastructure were implemented in various European countries with essential input based on international technology and knowledge transfer in the last decades.

Following the recommendation of WHO and good experiences made in Europe, the network partners of “NICE on RoadS - EU-Asia Network in Competence Enhancement on Road Safety” are of the opinion that development and implementation of new design guidelines, based on international technology and knowledge transfer can contribute significantly to safer roads in Asian countries like Thailand in the future.

The impact of improved road infrastructure (influencing element: ENVIRONMENT) on road traffic safety can be estimated on basis of Figure 1a.

In the framework of the Thai-E.C. project “Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai Universities” five partner universities from Germany, Hungary and Thailand are developing and testing a “Methodology for design guideline implementation based on international technology and knowledge transfer”.

With the planned methodology the partners want to foster the implementation process of design guidelines based on international technology and knowledge transfer in Thailand.

In this paper a first approach of the structure of the methodology is introduced.

4.2 Terms and definitions of technology and knowledge transfer

The term “technology transfer” can be defined as the diffusion of technological knowledge inside an economic area or from an industrialised to a developing country (Woll, 2008). Another similar definition defines technology transfer as the transfer of technological knowledge (e.g. research and development results) for application in production process. Here technology transfer can be realised between universities, inventors, research units and companies, between multi national companies, between different companies, between industrial countries, between industrialised countries and developing countries (Brockhaus, 1998). Transfer of practical and educational knowledge is not part of technology transfer (Brockhaus, 1998) and can be identified as knowledge transfer.

Following the two definitions the term “technology transfer” can be regarded in the context of this paper as follows:

Technology transfer in the field of road traffic infrastructure is the transfer of technological knowledge (research results, available guidelines and best practice) for application in the design process of road infrastructure, including the adaptation to national and local specifics. Technology transfer can be realised e.g. between universities, research units and further organisations from industrialised and developing/emerging countries.
Whereas knowledge transfer can be regarded in the context of this paper as follows:

**Knowledge transfer** can be defined as the exchange and transfer of practical and educational knowledge between universities, research units, organisations and further experts, stakeholders and interested persons e.g. in the design of road infrastructure or road traffic safety.

4.3 Design guidelines - status quo in Thailand and Europe
In European countries rules and regulations for the design of road infrastructure are normally defined in guidelines which are compulsory or partly recommendatory. If road and traffic engineers follow these rules and regulations, the design should have a high safety level.

<table>
<thead>
<tr>
<th>overall design guidelines according to the type of road</th>
<th>roads inside built-up areas</th>
<th>roads outside built-up areas</th>
<th>motorways</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAST</td>
<td>&quot;Guideline for the design of urban roads&quot;</td>
<td>&quot;Guideline for the design of highways&quot;</td>
<td>RAA &quot;Guideline for the design of autobahnen&quot;</td>
</tr>
<tr>
<td>RAL*</td>
<td>&quot;Guideline for the design of highways&quot;</td>
<td>&quot;Guideline for the design of highways&quot;</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>thematic guidelines and recommendations in addition to overall guidelines -examples-</th>
<th>roundabouts</th>
<th>signal control</th>
<th>capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAK &quot;Recommendation for the design of roundabouts&quot;</td>
<td>RILSA &quot;Guideline for the design of traffic signals&quot;</td>
<td>HBS &quot;German Highway Capacity Manual&quot;</td>
<td></td>
</tr>
<tr>
<td>RAA &quot;Guideline for the design of roundabouts&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>user group specific recommendations in addition to overall and thematic guidelines and recommendations -examples-</th>
<th>pedestrians</th>
<th>bicyclists</th>
<th>public transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFA &quot;Recommendation for the design of facilities for pedestrians&quot;</td>
<td>ERA &quot;Recommendation for the design of facilities for bicyclists&quot;</td>
<td>EAÖ &quot;Recommendation for the design of facilities for public transport&quot;</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4**: Structure of design guidelines used in the design of road infrastructure in Germany
Source: Vesper (2009)

German and Hungarian road engineers have for instance access to various design guidelines and recommendations which cover nearly all aspects of the design of road infrastructure. The selection of respective guidelines and recommendations, which need to be considered in the design process, depends mainly on the type of road, the subject of design and the affected road user groups by the planned road infrastructure. The structure of available German design guidelines is shown exemplarily in Figure 4.

Thai road engineers often have no such guidelines to follow because only a few national guidelines exist and relate to only a few topic areas. Even for topics where they are available, for most areas, no research based knowledge exists, which would adapt foreign guidelines or standards to national conditions. Instead of national guidelines, often guidelines from other countries like Japan, Australia or the United States are used and they are only available in foreign language and are not adapted to national conditions in Thailand. In many cases, road and traffic engineers, for lack of appropriate guidelines, have to design road infrastructure based only on individual decisions, assumptions or estimations which could be the reason for the inadequately designed roads especially from the point of road traffic safety.

Experiences of road safety audits and results of research projects executed by Thailand Accident Research Centre (TARC) confirm this statement. There is therefore an urgent need to
develop Thai national guidelines for the design of road infrastructure in different topic areas in order to provide research-based knowledge for target groups which are involved in the design process of road infrastructure and traffic control in Thailand.

4.4 Structure of Methodology
The “Methodology for design guideline implementation based on international technology and knowledge transfer” comprises different working phases with involvement of institutions, organisations and target groups which belong to different knowledge-levels. The structure of methodology is shown in Figure 5.

The first part of the methodology is the technology transfer of available design technologies from Europe to Thailand. Here design methods will be exchanged between international research organisations and institutions on the same knowledge level (horizontal transfer). Based on the results of first activity “exchange”, the transferred design technologies need to be adapted to national conditions. With adaptation one considers differences of behavioural aspects of road users as well as general aspects in the design like right/ left-hand driving, traffic signs or traffic rules in the design guidelines. In general one should consider that it depends on the specific subject, method or parameter of design technology, whether it needs to be adapted to national conditions or not. Here the spectrum of adaptation is in-
between the range of no adaptation up to full adaptation. Beside engineering aspects the adapted knowledge should meet requirements of the target groups “scientific institutions, associations and committees”, “universities and technical colleges” and “engineers, practitioners”. Here especially the scope and the preparation of knowledge should meet the respective requirements.

The adapted design technologies are ready for implementation in the second part of the methodology – the knowledge transfer. The main objective of this part is the knowledge transfer of generated and adapted knowledge from research level to lower knowledge levels like education, user and impact level (vertical transfer). Diffusion of knowledge can be realised amongst others by publications, campaigning, training and education as shown exemplarily in Figure 5. The diffusion of knowledge is an essential part of the proposed methodology because it makes the knowledge available for target groups in practice. Improvement of road traffic safety can only be achieved if the generated knowledge achieves the target groups and will be applied in practice.

The third part of the methodology – the application of knowledge - comprises the application of generated knowledge in the design of road infrastructure as well as in the use of road infrastructure by road users in practice. Here new design methods need to show their impact on road traffic safety. Further measures, like enforcement can contribute to behavioural changes of road users and can contribute to higher acceptance of new design methods.

4.5 Target groups
In order to implement the design guidelines in a successful way, several target groups need to be addressed. The design guidelines should meet amongst others the requirements of following target groups:

- universities and technical colleges,
  (multipliers of generated knowledge on education level),
- engineers and practitioners,
  (users of generated knowledge on user level),
- road users which belong to different user groups
  (beneficiaries of generated knowledge on impact level),
- scientific institutions, associations and committees for these purposes
  (promoting the process of design guideline implementation).

Institutions and organisations that are responsible for legal implementation of design guidelines as well as for the process of legal guideline implementation are not considered in this paper because this process differs in each country significantly. In this paper the legal implementation is mainly regarded as a parallel process. For this reason it is not mentioned in Figure 5.

4.6 Acceptance gaps in methodology
The methodology of design guideline implementation can be subdivided in different phases. Here one can distinguish between the research, diffusion and application phase. In each phase several institutions, organisations or person-groups from the same or different knowledge-levels are involved in the process. Subject of each implementation phase are one or more specific activities which will be realised during the phase. The chronological order of activities depends on the phase considered and can be conducted in general alternatively one after another or simultaneously, as shown in Figure 5.
As mentioned above, different parties (institutions, organisations or person groups) are involved in the implementation process and in this way they are involved also in the activities of the three implementation phases. The involved parties have often different characteristics (like objectives, requirements, behaviour ...), which can lead to acceptance gaps (gap 1 to gap 10) in the process of design guideline implementation (see Figure 5). In consequence of this fact, one main pre-condition of a successful “design-guideline implementation” is the overcoming of the mentioned acceptance gaps during the application of the methodology. In Table 2 typical issues or respective problems are listed exemplarily which could be the subject of acceptance gaps.

**Table 2: Acceptance gaps in the methodology for design guideline implementation**

<table>
<thead>
<tr>
<th>phase</th>
<th>activity</th>
<th>selected issues / problems which could be subject of acceptance gaps</th>
</tr>
</thead>
</table>
| research phase      | exchange                      | - determination of the subject of technology transfer,  
|                     |                               | - selection of appropriate methods and measures for technology transfer.                                                              |
|                     | adaptation to national        | - differentiation of methods and parameters, which can be / should be adapted or not (wide spectrum from no adaptation to full adaptation to national conditions, depending on considered methods and parameters),  
|                     | conditions                    | - adaptation of guideline structure and content according to requirements of target groups,  
|                     |                               | - consideration of behavioural aspects of road users in adaptation process.                                                            |
| diffusion phase     | publication                   | - way of guideline provision for target groups,  
|                     |                               | - language of publication,  
|                     |                               | - missing recognition for need of new guidelines.                                                                                 |
|                     | campaigning                   | - missing understanding of rules and function of new design methods / measures by road users,  
|                     |                               | - behavioural opposites to new design methods / measures.                                                                           |
|                     | training / education          | - need for consideration of new design methods and measures in lectures and training courses,  
|                     |                               | - readiness to adapt content of current lectures and training courses,  
|                     |                               | - provision of training and pre-training courses to target groups.                                                                   |
| application phase   | application in design         | - availability of new design methods for target groups,  
|                     |                               | - practicability of new design methods,  
|                     |                               | - comprehensibility of new design methods,  
|                     |                               | - recognition by public authority, awarding authority, etc.                                                                          |
|                     | behavioural adaptation        | - impact of new infrastructure design on behaviour of road user (physical and mental impact of new design method on road user),  
|                     |                               | - impact on workload of road user (cf. Fuller, 2005).                                                                               |
|                     | enforcement                   | - necessity of compulsory measures to influence behaviour of road users,  
|                     |                               | - general effectiveness of enforcement measures.                                                                                  |
4.7 Application of methodology
In the framework of the Thai-E.C. project “Improving Road Traffic Safety in Thailand – A Common Challenge for European and Thai Universities” the proposed methodology for design guideline implementation will be practically tested by the implementation of two design guidelines in Thailand.

Here one design guideline will deal with the “Design of traffic control at signalised intersections” and a second one with the “Design of roundabouts” in Thailand.

The outlines of the two guidelines are introduced by Vesper et al. (2010) and Koren et al. (2010) in more detail.

5. FORECAST
It is acknowledged that the design of road infrastructure has a strong influence on road traffic safety. According to Treat (1977) more than 40% of accidents are influenced by the element “Environment” which comprises road infrastructure.

Several studies (Brilon, 2008, FHWA, 2000, Elvik et al., 2009) have shown that proven design methods and measures – e.g. with the view on road traffic safety - can be transferred successfully from one country to another.

The new approach of a methodology for design guideline implementation gives an overview of the implementation process of design guidelines based on international technology and knowledge transfer. The methodology will foster the implementation of design guidelines and the application of research based knowledge in the design process of road infrastructure in Thailand.

The authors are convinced that the guideline implementation and the associated design of safer road infrastructure will be a main measure to improve road traffic safety and to counteract the current road traffic safety situation especially in emerging and developing countries in the future.

6. ACKNOWLEDGEMENTS
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REFERENCES


DRIVER’S RISK PERCEPTION ASSESSMENT. THE CASE OF HIGHWAYS WITH POOR GEOMETRIC CHARACTERISTICS, IN HEAVY TRAFFIC CONDITIONS.

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Abstract
The scope of this paper is to assess-interpret the behaviour of experienced and non-experienced drivers in high-way driving circumstances, where, due to intense traffic and non-proper road designing, the level of the provided service is low and the driving task becomes a stressful procedure.

In order to assess-estimate the level of drivers’ stress, a several numbers or drivers’ behaviour characteristics were measured (velocity, acceleration-deceleration, driving track etc.). The monitoring of driving behaviour was recorded using the VBOX II and VideoVbox (Racelogic Ltd, U.K) device, which is a Differential GPS based set of instruments, including a 3D accelerometer.

The setup of the research was to monitor driving behaviour of 8 different drivers, driving 2 different typical (for Greek car-fleet) passenger cars, on typical sections of national highway network.

The trial tests, in order to assess drivers’ perception, were carried out during peek hours (Morning and Noon) as they are defined using Highway Capacity Manual Procedure.

The present paper presents the first results of a research effort, which is dedicated to the detailed drivers’ behaviour analysis. It is obvious that the proper highway design should not only be based on geometric aspects, but on oncoming traffic conditions, especially on high and heavy traffic volume highways.

A lot of research has to be done on drivers’ behavioural analysis, in order to achieve better road alignment (beyond standard regulations and guidelines) and better signing, with emphasis to safety.

1 INTRODUCTION
In the present paper the first results of research work are presented, concerning drivers’ risk perception through the examination of several categories of drivers’ behaviours (both experienced and novice) in a highway road that offers a low accommodation level and makes driving a stressful task, due to increased traffic burden, high velocities that vehicles develop, combined with small time-place distances that keep between them.

In order to estimate this stress, the velocity and mainly the acceleration profiles of several drivers have been recorded and analysed. Next, these measurements were formed into charts, in which - after careful observation – there was an attempt to interpret drivers’ behaviour (stressful reactions) and to compare factors that can affect it.

All the conditions under which the research was conducted (equipment, vehicles, drivers, road geometry, time period measurements) as well as post processing data are presented analytically. Furthermore, research conclusions are presented and suggestions are also made for expansion of the research, as well as for further supplementary study.

The main goal of this study is to improve the level of road safety in road parts with equivalent traffic profile, improving also driving conditions.
2 BASIC PARAMETERS ANALYSIS

2.1 CRASH RISK PERCEPTION
Taking into consideration a great number of research work with reference to the analysis of parameters that affect driving behaviour, one finally wonders what can lead to predicting driving behaviour, especially when facing a potential risk for crash.(Grayson G.B., 2006, Deery, H.A., 1999, Williams, A.F., 2003 and Farrow, J.A. and Brissing, P., 1990).

The basic implement that can help the analysis, is the correlation between driver’s potential risk perception and the level-goal of the acceptance of the fact that danger does exist. In that case, the right crash risk perception means that a driver intends to drive safe when he will have exceeded the upper level of risk perception, that is when he totally accepts that the current situation is dangerous and not just a challenge or a driving excitement.

Risk perception in general is for a significant number of theoretical models a basic parameter of driving behaviour assessment. This applies even to the driving behaviour analysis of inexperienced drivers, who although they are in the procedure of developing self-adjustment behaviour abilities, risk perception is the most crucial factor of their driving behaviour definition.

2.2 OVERESTIMATED PERCEPTION OF DRIVING SKILLS AND UNDERESTIMATION OF DRIVING DEMANDS.
Over-self-estimation of a driver’s driving skills combined with the evolution of vehicles’ possibilities is considered a critical risk factor, especially for drivers that have recently acquired a vehicle of high possibilities, while for years they had been driving a vehicle of less possibilities and also for young drivers who drive vehicles with increased horsepower or illegally improved. Nevertheless, increased self over estimation regarding driving skills – that a driver thinks he has – can have other than negative consequences.

High self overestimation of driving skills as a result of pushing driving performance to the edge, can - under circumstances - contribute to real improvement of driving ability. There is no relevant research that confirms such a conclusion and probably there ought to be made such an effort, although there is scepticism that, if there is evidence that high self overestimation can sometimes improve driving ability, this would result in an over inflated driving ability perception in some other cases, that will -in turn- have harmful consequences.

We should also deal with the question, whether high self overestimation truly improves driving ability and whether this ability influences driver’s self perception of what kind of driving skills a certain situation demands. Of course when someone comprehends his own driving ability it doesn’t mean that he also has a relative risk perception. Driving ability assessment is more relevant to the risks that lurk on the road, meaning that their perception by the driver means at the same time that he detects them where they appear and he also comprehends their demands.

Moreover, it has been recorded that behaviours regarding the acceptance that one does drive with extreme velocity, depend on certain conditions risk perception, including roadway familiarity, the belief that one can manage to drive safe in high velocities and also including driving in absence of other cars on the road etc.

2.3 STRESS EFFECT ON DRIVING.
When someone is under stress, he usually has a negative predisposition for a crash. Driving ability and moreover driver’s safety can be negatively influenced by the inner and outer conditions of the road that can cause cumulative stress. For example a driver who is triggered by factors that exist in a certain surrounding (for example an intense conversation on the cell
phone or traffic jam while he is in a hurry) has cumulative stress and he is exposed to a high risk accident.

Drivers that face several serious problems in their life (family problems, social, health problems or job problems) come up against similar risks.

2.4 THE EFFECT OF HABIT ON DRIVING.
Negative effect of habit on driving is demonstrated by the fact that risky driving can be detected without the driver having to take a risk on purpose. For example, a driver enters a car and having no conscience of the risk he is about to run, he completely forgets to fasten his seat belt. It has to do with routine movements that although they become a habit as the years go by, they have less to do with other deliberate choices of the driver, as mentioned before. Without reference to whether a driver intends to drive safe or not, the strength of habit exceeds cognitive procedure.

Several other researchers concerning other aspects of driving behaviours argue that the relationship between intention and attitude is not that strong when it comes to habit, like the one with the seat belt mentioned before (Webb, T.L. and Sheeran, P., 2006). A brief outline of their conclusions mentions that between several behaviours that are usually followed in stable conditions, the older ones have better predicted future behaviours, while the driver’s intention was the one that could better predict future behaviours, when it concerned less common behaviours taking place in unstable conditions.

3. EXPERIMENTAL PROCEDURE

3.1. Equipment
VBOX II and VideoVbox devices by Racelogic Ltd that were used for recording the vehicles’ movement characteristics are all based on differential device GPS that offers great accuracy in relevant movements measurements. Measured velocities have an accuracy of ± 0.01 km/h and the same goes for estimated accelerations.

GPS’s function demands an open sky in the measurement field (and avoiding populated fields or forests) so that there is always a minimum of 3-4 located satellites for the measurements to have the accuracy demanded.

The Devices used set (fig. 1) includes a central unit where a GPS antenna, a braking sensor and an Inertial Measurement Unit, (3D Accelerometer).

VBOX II and VideoVBOX can collect almost the entire vehicle’s movement relevant data without the presence of a PC unit. Special software is used for data process that can reproduce the vehicle’s movement, showing all selected parameters (fig.2), while at the same time it provides graphic display of the vehicle’s trajectory, with reference to the roadway boundaries at the same time with the change of the vehicle’s movement parameters.(fig.3). The innovative element of Video Box is that it offers us the possibility of visual assessment of the driver’s behaviour all along the way.
Figure 1: VBOX II & VideoVbox. Vehicle’s movement characteristics recording devices.

Figure 2: VBOX II & VideoVbox. Real time visual inspection of vehicle’s movement characteristics combined with driver’s viewpoint.

Figure 3: Vehicle’s movement parameters and trajectory recording.
Some of the movement characteristics and the relevant accuracy that are directly recorded are presented to the following Table 1:

Table 1: Measuring Specifications.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
<th>Accuracy using DGPS</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>0.1 km/h</td>
<td>0.1 km/h</td>
<td>0.01 km/h</td>
</tr>
<tr>
<td>Distance</td>
<td>0.05%</td>
<td>0.05%</td>
<td>1 cm</td>
</tr>
<tr>
<td>Position</td>
<td>3 m</td>
<td>1.8 m</td>
<td>1 cm</td>
</tr>
<tr>
<td>Elevation</td>
<td>6 m</td>
<td>3 m</td>
<td>1 cm</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.01 g</td>
</tr>
<tr>
<td>Heading</td>
<td>0.1 degrees</td>
<td>0.1 degrees</td>
<td>0.1 degrees</td>
</tr>
</tbody>
</table>

Other useful parameters that can be recorded are: Radius of turn, Heading, Trajectory layout.

3.2. Planning of Field Operation Tests

For conclusions, experimental tests have been conducted from which original data has been collected. After data processing, conclusions are drawn that indicate drivers’ risk perception extent of influence by traffic conditions that exist in a highway.

The problem of road safety due to extreme traffic conditions occurs mainly to peripheral ring roads of the major cities in Greece. That is due to high traffic volumes combined with high operational speeds (V85) and occasionally with improper geometric characteristics. Taking into account that the majority of these roads was designed several decades ago, it is obvious that are not compatible with the new generations of vehicles and their needs, so is was rational to setup the experimental procedure based on a typical ring road. The selected road is the Peripheral Ring Road of Thessaloniki which is the 2nd major city in Greece. This road was constructed during the first half of the 80s, it has 3 lanes per direction, without emergency lane. The two directions are separated with a median strip equipped with metal barriers as a restraint system.

![Figure 4: The Ring Road of Thessaloniki (Test Site)](image)

Two different types of passenger cars, by means of their horse power, were selected (Volkswagen GOLF 1600cc and Hyundai Getz 1200cc). The selection of cars was based on international classification and on the most common types travelling in Greece.
The choice of drivers was based only on their actual driving experience, by this considering 5 years of driving experience and 100,000 km travelled as a limit to distinguish the experienced and the non experienced drivers. A total number of 6 drivers with similar social characteristics, where selected and each one of them travelled over the selected road segments. Half of the selected drivers were experienced.

Preparative to eliminating the influence of weather condition, lighting condition and surrounding environment, the road segments selected having similar surrounding environment. The testing procedure was carried out during morning and afternoon rush hours (8:00-9:30 and 17:00-18:00). All the instrumentation could not be seen by the drivers, so that they wouldn’t demonstrate abnormal behaviours.

4. Experimental Results.
The results are presented as diagrams:
- Speed vs. distance
- Acceleration vs. distance.

The diagrams from fig5 to fig8 are representative samples.

Figure 5: Speed vs. Distance (Volkswagen GOLF 1600cc)

Figure 6: Acceleration vs. Distance (Volkswagen GOLF 1600cc)
Figure 7: Speed vs. Distance (Hyundai Getz 1200cc)

Figure 8: Speed vs. Distance (Hyundai Getz 1200cc)
5. Conclusions.

The first conclusions that derive from the analysis of the results are:

- Driving experience is a very critical implement, regarding the distribution of the measured speeds and the reduction of the acceleration-deceleration peak values. Obviously, experienced drivers, although they drive faster, they do not react abruptly (they are not braking often and hardly), and that results to a remarkable decrease to the observed collisions.

- The poor geometry of the road (narrow lanes, downhill slope, lack of emergency lane etc) enhances the insecurity of the non experienced drivers, resulting thus to a more often and more rapid braking.

- The scope of the travel (work, amusement etc) affects mostly the speeding and accelerating profile. During morning rush hours, a remarkable variation in speeding peeks is being observed. During afternoon rush hours the speeding profiles were, by far, more flat.

- Driving a low horse power vehicle is a significant disadvantage to the non experienced drivers, because they feel that they don’t have the driving skills to react properly to a continuous acceleration-deceleration profile. This fact enhances the insecurity of the non experienced drivers, resulting thus to react even more abruptly.

- As it was observed the aggressive driving style of some drivers mostly influences the traffic risk perception of non experienced drivers.

Obviously, the methodology and the analysis of the results is a first approach to the ambitious research scope. Furthermore, an enhanced research effort should be contacted, using a big variety of vehicles, traffic volumes, drivers, road characteristics etc., in order to define and adopt a “stress index” and to evaluate the dangerousness of existing urban or peri-urban motorways.

REFERENCES


Grayson G. B., (Transport Research Laboratory) and Groeger J. A., (University of Surrey),18-1-2006. «Risk, hazard perception and perceived control», Proceedings of the Novice Drivers Conference, Department for Transport.


Stimulating Traffic Safety of (Delivery) Vans by Enhancing the Company’s Safety Culture
Annick Starren, TNO, The Netherlands

Development of Road Safety Network in Cambodia
Chandy Meas, Handicap International Belgium, Cambodia

Safety Culture in Bus Transport Compared to Rail and Air Transport
Torkel Bjørnskau, Institute of Transport Economics, Norway

An Innovative Approach to Addressing Heavy Commercial Vehicle Safety
Adam Ritzinger, ARRB Group Ltd, Australia

Examples of Approachable Fatigue Management Practices in Transport Companies in the Netherlands
Annick Starren, TNO, The Netherlands
STIMULATING TRAFFIC SAFETY OF (DELIVERY) VANS BY ENHANCING THE COMPANY’S SAFETY CULTURE

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Key words: transport safety, traffic safety, safety management, safety culture, learning, core business

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ABSTRACT
Statistics in the Netherlands show that lorry vans are more often involved in road accidents with severe consequences. This is due to characteristics of the vans in combination with characteristics of the drivers. Also, many vans are used for transportation in a business context, e.g. service companies, carpenters, (industrial) contractors, couriers, etcetera. In this research the potential incentives for such companies to invest in transport safety have been investigated.

A difference was made between companies with little or no attention to safety on the one hand (reactive safety culture) and companies that already pay attention to safety (proactive safety culture). Companies were scored on their level of safety culture, reactive or proactive, based on the safety culture ladder (Hearts & Minds model; Hudson, 2007). The research question was: "how can companies with (delivery-) vans with a reactive safety culture, be encouraged to pay (more) attention to road safety? This question is examined through 10 company visits. Interviews were held with representatives of the staff departments (quality, safety), management and the workfloor.

The investigation has led to an overview of different possible measures to develop or introduce in the companies. The point of departure has always been that measures shall be consistent with the primary process of the companies to be effective and sustainable.

1. Introduction
This study has been conducted for the Dutch Ministry of Transport, Public Works and Water management which strives to reduce the accidents with lorry vans on the road. A study into safety culture in road haulage has already been done. This has resulted in the development of the so-called Safety Scan for transport companies. By this tool potential safety measures can
be diagnosed. The success of the Safety Scan depends on the safety culture within a venture. Entrepreneurs who already attach importance to (road) safety will be stimulated by the tool to improve their safety level, but the remaining companies do not. This is by far the largest part of the sector. These must be stimulated in a different way to lead them to take road safety measures. Both for freight and lorry vans, this will be a formidable challenge: how can entrepreneurs without intrinsic motivation for road safety be stimulated to take measures nevertheless? In this research, the lorry vans are issued.

2. Background
The last years social conscience has grown that road safety of lorry vans knows its own specific problems. Meanwhile approximately 900,000 lorry vans drive within the Netherlands, varying in use of couriers, painter companies, plumbers, contractors, etcetera. The following characteristics of lorry vans reflect the urgency to ask for specific attention to road safety problems of lorry vans (Dutch Ministry of Transport, Public Works and Water Management; 2009):

- A relatively high involvement in serious accidents;
- The number of lorry vans has grown explosively over the previous decades in the Netherlands;
- There is no additional driving training necessary whereas it really concerns another vehicle than a private car (less visibility, larger mass, cargo);
- They drive intensively on the underlying road network where they come frequently into contact with vulnerable people taking part in traffic;
- They frequently drive under time pressure by a tight planning;
- The drivers generally do not drive in their own car;
- They are frequently controlled by young drivers with little driving experience.

The ministry wants to know if there are possibilities to motivate the (concerning) large part of (lorry van) carriers who have little or no attention for safety culture to invest in road safety. Except for an estimated 10% of best entrepreneurs, there seems to be no intrinsic motivation or there is hardly any present. There is a need for insight in the characteristics of companies with lorry vans that are determinative for the degree in which a company is prepared to invest in road safety. Earlier study into road safety culture in freight has shown already that the motivation for road safety goes further than the motivation of the driver(s) himself: aspects of the company or the role of management are of vital importance for the degree in which road safety gets attention (Gort et al., 2003; H&SE, 2009). Also, there is a need for insight in the potential role of the government in road safety and possibly stimulate the offset of a safety culture along new ways.

Additional point of interest is to find safety measures that have a lasting effect. In this study, our assumption is that both the motivation for road safety and the guarantee of road safety measures increases when measures connect with the primary process (‘the corebusiness’). In general, safety measures are more accepted, more effective and even more efficient as they connect to the company’s corebusiness (Gort & Starren, 2006). This applies for both measures initiated internally and for measures from an external party such as the government. Characteristic for the driving task in companies that use lorry vans is that it is generally purely supportive to the company’s core activities. In other words, the transport with the van is no corebusiness. Only in courier business, the driving task is the corebusiness. Nevertheless, this observation reinforces the need to find stimuli related to the primary process to increase attention for road safety. For example, think of stimuli related to insurance constructions, contractor relations, company culture and - strategy, advantages from trade...
associations, knowledge/recommendations for free or discounts from accountants, creating accessibility advantages or more business opportunities/deals in case of safe performance. Particularly for Small Medium-Sized Enterprises (SME) it is important that road safety measures connect with the business processes that are already present.

3. Methods

3.1 Target group
Under lorry vans is meant all vehicles that are arranged for goods transport with up to an admissible weight of 3500 kilograms. These are popular under several user groups such as contractors, maintenance companies, couriers and SME.

3.2 Research questions
To answer the main question, namely: 'How can companies using lorry vans with a reactive safety culture be stimulated to give more attention to road safety? we defined a couple of sub questions:

1. In what way differ the companies where there is already a safety culture present with respect to the companies where road safety does not get (or hardly any) attention?
2. What possibilities are there for both categories to commit them to give more attention to road safety?
3. In what way can entrepreneurs be stimulated to take road safety measures, or from the internal motivation of the company or by means of external stimulation measures?

These questions have been examined by means of 10 company visits. Interviews were kept with at least one representative from (general) management, one from the safety perspective (safety manager, safety advisor, head of maintenance, head of car fleet) and one from the workfloor. The interview consisted of 3 types of questions:

- General questions (size, markets, nature of the work, products, customers, etcetera);
- Questions to score the company on their level of safety culture by assessment of their activities according to the model of the safety culture ladder (Hudson, 2007);
- Questions regarding to the linking factors between safety and the corebusiness according to the Safety@corebusiness© model (Gort & Starren, 2006).

Next, the results have been analyzed, the characteristic of companies per safety phase as well the opportunities for coupling with the corebusiness (favorable measures) per safety phase.

As a result the list of opportunities for favorable measures has been presented to an expert group and has been reviewed. The question was what the most potential measures are for implementation in the sector (acceptance, effectiveness), particularly for the reactive companies?

3.3 The Research framework
3.3.1 Safety culture ladder
In this study we distinguished between several phases of safety culture at companies. This classification has been based on the Hearts & Minds program of Shell that has been developed by the University Leiden (Hudson, 2003). The program distinguished pathological, reactive, calculative and proactive phases depicted in the so called safety ladder step model. Characteristic for the pathological phase is that companies do not consider safety as important as long as they do not become convicted for any safety violation. In the reactive phase safety
only becomes important as soon as an accident has occurred. Characteristic for the calculative phase is that systems are present within the companies in which safety is controlled, such as a safety management system or recording system. Companies at the proactive stage are active in search of risks that can arise and ‘manage’ in accordance with these risks. Moreover, there is also a generative phase of safety culture, but in practice companies at this stage hardly exist.

Figure 1 shows the passage of a pathological safety culture to a generative safety culture. As the figure shows, an increasing faith and so-called ‘informedness’ (= openness to information) are the necessary conditions for a development of safety culture through the phases.

![Figure 1: Safety culture step ladder](image)

For the road safety of lorry vans, this means that we expect the largest group of companies to be in the bottom two phases of development: the pathological and reactive phase with respect to safety culture. In these phases companies only do what is seen as legally obliged (APK (yearly obliged testing for vehicles of 3 years and older in the Netherlands), insurer), but they are not prepared to take extra initiatives. For the analysis we made a distinction between companies with a pathological/reactive safety culture, those with a calculative safety culture and those with a proactive safety culture.

3.3.2 Safety@corebusiness©

A tight relationship between safety and core business means that safety issues are perceived as a critical element of all relevant processes and activities in the organisation, e.g. daily decisions, investments, purchasing, management of employees and work practices. To identify these factors, the theoretical framework Safety@corbusiness© is developed and validated in several companies by means of case studies. Examples of safety measures that are embedded in the core business are: safety targets in the assessment of management, less focus on short-term investments, a drive to learn from errors and other experiences or the implementation of safety in external legislation (Gort & Starren, 2006). We use this concept because it is important to design and implement safety measures in companies that last.

The Model Safety@corebusiness© is shown in Figure 2.
Key aspects
Core business (purple), described in terms of:
- Activities (core activities the company performs in its production process);
- Values (core values shared among management and all employees);
- Competencies (core competencies necessary for the primary production process inc. individual and collective learning).

Safety characteristics (blue), described in terms of:
- Structure (all structures, systems and processes, relations between departments and employees and pattern of interactions, installed to ensure production in a safe manner);
- Culture (all shared values, norms, perceptions and assumptions about safety and risks);
- Learning (how the organisation and individual employees learn from earlier experiences).

Connections (orange arrows) between safety and core business.

External surroundings (green) with influence on the organisation, described in terms of:
- Shareholder and stakeholder pressure and developments in networks (structure);
- Groups of people to which employees feel connected (culture);
- Developments in the sector or in the field of management models and safety (learning).

Tuning into the external surroundings by the organisation (black arrows), in other words, those factors in the context of the organisation that influence safety thinking and action within the organisation.

The actual safety output of the organisation (red), measured, for instance, in:
- Input indicators: % of new employees with safety training, contracts with safety paragraph, contracting of work with safety arrangements;
- Throughput indicators: poor housekeeping, high turnover of employees, management time on safety;
Output indicators: accidents, days of sickness absence, unscheduled equipment breakdowns, low employee morale.

By use of a (self-) assessment tool the, the coupling and discrepancies between the company’s core business and the way they deal with safety can be measured. Relevant parts of this tool are used to formulate questions for the interviews in this study.

4. Results

To answer the first research question, there has been looked at the general differences between the companies with a reactive and proactive safety culture, and what this means this for possible road safety measures. A number of general differences have been found between companies with a reactive/calculative or proactive safety culture. Companies with a proactive safety culture distinguish themselves because they:

- have customers that make demands with regard to the safety level;
- have another nature of the work;
- are attached to certain values in the company as a component of the company culture;
- feel less threatened by competition in the market;
- are attached to their image on the market;
- have an active relation with their insurer;
- give attention to Quality, Safety and Environment policy;
- have a management that has an committed attitude;
- have a overall proactive management and disposition;
- spend time on monitoring, registering and giving feedback as a result of which learning from incidents and accidents becomes possible.

The question is what these differences between the companies mean for the way in which investments in road safety can be stimulated. The differences are frequently inherent to the primary processes of the company or its 'corporate culture' and will not easily change by means of the entrance of (transport/ road) safety. E.g. a strong learning capacity, or a certain management supervision cannot easily be created for road safety. More troublesome is to change the nature of the product or the market itself.

More strongly still, it would work the other way around: certain type of road safety measures will only produce results when they dovetail the company culture (and therefore a certain level of safety culture has already been reached). The research conducted has led to an overview of possibilities for several measures to develop or introduce. The main point thereby has always been that measures must dovetail the primary process of the companies for effectiveness and durability to be.

Beside the above observations it was notable that:

- we hardly have found companies where people were really hurried. There were also hardly any lesion damage or serious accidents occurred within the companies that were interviewed;
- overall, companies find it important that the lorry van is technically in order so that there is no time loss underway: participation in traffic is a necessary component of the work; and
- also, it was notable that companies that companies with (sectoral) OSH certification or management systems, lay no systematic link with road safety.
To answer the second question opportunities were inventoried for the coupling of road safety measures to the company processes. The idea is that in this way measures are accepted faster and will last longer. They give an indication of acceptance and anchoring of possible measures. Possibilities for implementation and associated bottlenecks have been inventoried according to the Safety@corebusiness© model (Gort & Starren, 2006) and were divided in:

- **Internal opportunities for coupling (based on structural, cultural and learning mechanisms):** both the safety aspects that are a stimulant (stimulants) as well as those aspects that are an obstruction (barriers) for the core business are inventoried. On the basis of these internal opportunities favorable internal measures can be stipulated.

- **External opportunities for coupling:** stimulants or restrictions in relation to external aspects, i.e. external aspects which interests companies because they also offer opportunities for the company ambitions. But the opposite can apply as well because these aspects lack a connection with company objectives or even conflict with them (barriers). On the basis of these external opportunities favorable external measures (in particular initiated by government) can be stipulated.

This research has conducted to a list of opportunities for favorable measures. These have been presented to and reviewed by an expert group. The question was: “What possibilities for implementation offer the most of chance to base effective measures on, particularly with regard to reactive companies?” In short the following internal opportunities for favorable measures to establish an increased attention to road safety at lorry van companies are:

1. Incorporate road safety in Quality, Safety and Environment policy;
2. Incorporate road safety in the personnel policy;
3. Give road safety a permanent agenda point in management meetings;
4. Management gives attention to their example role and image with respect to (transportation) safety;
5. Road safety and traffic accidents have to be incorporated in the existing company recordings and analysis systems; and
6. Learning from accidents has to be a fixed component of process improvement.

Of the above range of favorable internal opportunities, two measures were best rated by the experts. First incorporating road safety in Quality, Safety and Environment policy and second involving road safety aspects in personnel policy (HRM). Other potential measures addressed a felt priority for safety by the management. However, this is mostly a consequence of the existing culture in the company. Also, it was rated important to have insight in risks and the number of incidents and damages.

The following external opportunities for favorable measures to establish an increased attention to road safety at lorry van companies, for governments or other parties, are

1. Incorporating information in the field of road safety and damage recordings in the communication with external parties (government, provinces, municipalities, insurers, customers);
2. Join in line with improvement initiatives aimed at improving the quality and image of the sector;
3. Incorporate road safety of lorry vans more explicitly as an aspect of enforcement and inspection.
The tables below give an overview of favorable measures and the applicability of the measures for the different phases of safety culture at companies. The favorable measures are distinguished for the companies with a reactive (Table 1), calculative (Table 2) and proactive (Table 3) safety culture.

*Please note:* the group of companies with a `pathological' safety culture (the bottom step on the safety ladder) is most likely to be strongly represented in lorry van traffic on the road. Unfortunately, these types of companies were underrepresented in the cases. Favorable measures for the pathological companies have been added on the basis of conversations with commission agents, among other things an insurer and a damage consultant, the report of the workshop and ready knowledge concerning unwilling companies in several sectors.

Table 1: Reactive measures

<table>
<thead>
<tr>
<th>Reactive</th>
<th>Measures for companies (internal): structure/culture and learning (based on intrinsic motivation)</th>
<th>Measures from externals (based on extrinsic motivation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive</td>
<td>A: not willing (pathological)</td>
<td>A: here only enforcement will work</td>
</tr>
<tr>
<td></td>
<td>A: not applicable (it will not come from themselves)</td>
<td>Local governments:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Demand requirements at spending licenses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Demand requirements through the park management organisation in company areas regarding establishment and participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Coupling of accessibility requirements, window times and workable hours (WBU) to road safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Government:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Stimulation of import of blackbox/boardcomputer which registers the driving behaviour in lorry vans (on behalf of speed restriction and return of damage and driving behaviour)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Reinforcement of police controls (speeding, keeping distance) on lorry vans and topic operations (stuwage and overloading) by IVW1 and AI2 (company visits)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o Public benchmarking by means of a Internet platform or a Quality</td>
</tr>
</tbody>
</table>

1 IVW (Inspectie Verkeer en Waterstaat: Inspectorate of Transport and Watermanagement
2 AI (ArbeidsInspectie): Workforce inspectorate
mark (transportation) safety

Sector/client:
- Dovetail sector initiatives like for example road safety obliged within VCA
- Public benchmarking, or safety quality mark of clients

Insurer:
- Price establishment on the basis of road safety performance, possibly based on the Safety Scans or other approachable damage recording system.

B: potentially willing
- Appoint road safety management meetings explicitly wherever possible
- Register damage and accidents by means of approachable recording system (at preference also file style information by means of the blackbox) and use this as an learning experience
- Organize driving skill trainings ('Nieuwe Rijden'3) and combine this with attention for road safety, for example in a start speech or the associated communication message

B: Here awareness and stimulation initiatives work
- The measures as called under A also work for the potentially willing companies

Sector:
- Connect with sector image campaign, aimed at importance and advantages for the driver and management, possibly coupled at ‘Nieuwe Rijden’.

Insurers:
- Awareness of road safety and the financial consequences by insurers, particularly aimed at the manager

Table 2: Calculative measures

<table>
<thead>
<tr>
<th>Measures for companies (internal): structure/culture and learning (based on intrinsic motivation)</th>
<th>Measures from externals (based on extrinsic motivation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculative</td>
<td>Here tools for monitoring and improvement work.</td>
</tr>
<tr>
<td>- Register damage and accidents and use as a learning experience (preferably also file style information by means of the blackbox) and connect this to recording systems for fuel consumption</td>
<td></td>
</tr>
<tr>
<td>- Use monitor of the SafetyScan and Safety Monitor</td>
<td></td>
</tr>
<tr>
<td>Government:</td>
<td></td>
</tr>
<tr>
<td>- Stimulate recording of road safety using for example SafetyScan/Safety monitor, which can be used specifically for monitoring road</td>
<td></td>
</tr>
</tbody>
</table>

3Het Nieuwe Rijden: Dutch television campaign on the ‘safe and sustainable driving’ style
5. Conclusion

In this study the potential measures to increase the awareness for road safety in companies, which use lorry vans, are inventoried. Underlying assumption is that measures that are aligned with the core business processes of the company will have a better acceptance, be more effective and have a lasting impact. Based on interviews with the 10 companies involved in this study it is shown that the companies with a different phase of safety culture also differ in their general business structures, cultural values and learning processes. Therefore different safety measures are suggested per safety culture phase. Potential effective measures for companies that already invest in (road) safety (proactive culture), are: the incorporation of road safety in existing internal quality, safety and environment management systems, in HRM systems, and in integrated concepts such as CSR and monitoring of best practices.

The largest target group appears the most difficult group to reach: the companies with a pathological/ reactive safety culture. These companies lack the intrinsic motivation to take up road safety: safety lacks priority and is not considered as a component of the primary process. Moreover, the associated risks are generally covered by taking damage insurance. These companies don’t want extra administrative tax of recording and monitoring. Decision-making in these companies is generally purely cost-based. To all probability this fact must be

Table 3: Proactive measures

<table>
<thead>
<tr>
<th>Measures for companies (internal): structure/culture and learning (based on intrinsic motivation)</th>
<th>Measures from externals (based on extrinsic motivation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Incorporate road safety in existing internal quality, safety and environment management systems</td>
<td>- Here no stimulation is necessary. However, monitoring is desirable.</td>
</tr>
<tr>
<td>- Take road safety as core competence or as a requirement of professional skill</td>
<td>- Government:</td>
</tr>
<tr>
<td>- Use the Safety Scan and Safety Monitor</td>
<td>- Stimulate a benchmark site, in which road safety is coupled to integrated concepts such as CSR</td>
</tr>
<tr>
<td>- Use damage and traffic accidents to learn within the framework of quality improvement</td>
<td>- Facilitate an Internet site /databank with which knowledge can be spread concerning best practice with regard to road safety</td>
</tr>
</tbody>
</table>

Insurers and/or lease companies:
- Make financial costs of incidents and accidents transparent and the savings which you can gain from it
accepted as rapidly given. For these companies only a stick behind the door will work. From
the list of measures mentioned so far, (obliged) implementation of a boardcomputer/blackbox
is a favorable possibility for change in the sector to initiate safe driving. Registration and
analysis of driving behavior offers insight in damages, and the unsafe behavior that lies at the
basis of that. Moreover, it offers the possibility to give feedback on this information. Insight
in unsafe behavior and returning feedback on this are basic elements for stimulating a safety
culture.

REFERENCES

Dutch Ministry of Transport, Public Works and Water management. Retrieved November 12,
2009, from http://www.verkeerenwaterstaat.nl/onderwerpen/verkeersveiligheid/050_veilig_vracht-
_en_bestelverkeer/180_veilig_bestelverkeer/

Veiligheidsprestatie–indicatoren in het beroepsgoederenvervoer. Den Haag: Ministerie van
Verkeer & Waterstaat.

corebusiness. TNO publication.

H&SE, Leaflet: Driving at work - Managing work-related road safety, Retrieved November


45, 697-722.

Culture bestelverkeer: onderzoek naar de mogelijkheden om te investeren in
verkeersveiligheid in het bestelverkeer. TNO publication.
DEVELOPMENT OF ROAD SAFETY NETWORK IN CAMBODIA

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ABSTRACT

The rapid rise in motorization, road improvement, and general lack of road safety education, law enforcement, and public awareness has contributed to the alarming rise in road crashes and casualties in Cambodia. Over the last five years, the number of road crashes has increased by 150% and the number of fatalities has almost doubled. The main cause of road crashes was from human error such as speeding, drunk-driving, and dangerous overtaking.

Work-related road crashes are a growing concern in Cambodia as the country is experiencing an economic boom over the past decade, with business and trade opportunities increasing rapidly along with the improving transport infrastructure, however, the dangers posed to employees on the road while performing work-related responsibilities is a forgotten element of the road safety problem in Cambodia.

The National Road Safety Committee of Cambodia, with the support of Asian Development Bank (ADB), developed Road Safety Action Plan, in which The National Road Safety Committee’s policy is to work with the various government and non-government organizations as partners in order to increase the potential for better results in promoting road safety, and maximize scarce resources. So far, due staff capacity and financial resources, the National Road Safety Committee (NRSC) yet implemented much on it. Seeing the gap, Handicap International Belgium (HIB) developed an initiative of developing the Road Safety Network in Cambodia. It was a good example tackling the situation while the government is still lack of resources for implementation.

In this paper, an attempt has been made to describe the experience of creation of the Road Safety Network, where the resources are very scarce. Detailed description of the
project including objectives, method, strategy, monitoring and evaluation technique, challenges and lessons learning from the project are also highlighted. At the very outset of the paper, a brief review of road safety problems particularly work related road crash in Cambodia are also described.

1 BACKGROUND

1.1. Road Safety Overview in Cambodia

Given its relative stability and growth in recent years, Cambodia has seen a rapid increase in its volume of road traffic over the last three years. At the same time, weak traffic regulations, insufficient enforcement of the new road traffic law, improvement of the road network (allowing speed increases), lack of road safety education, and the inadequacy of public health infrastructures in providing treatment for traffic injuries have led to a rapidly rising number of road crashes and casualties.

In first semester of 2009, according to Road Crash and Victim Information System (RCVIS) \(^1\) - a report from traffic police and health combination showed that more than 4 persons die and at least 70 are injured daily on the roads of Cambodia. Indeed, the number of fatalities has been almost doubled within the last five years, 2004 to 2009.

Alarmingly, 54 % of casualties are among the active part of the population (age 15 to 29), with farmers and students the overwhelming majority. About 73% of all casualties and deaths are male (RCVIS 2008). Consequently, the groups most affected are invariably the main breadwinner in the household resulting in a loss of income for the family, high medical and/or funeral costs and in the case of injury rehabilitation costs.

1.2. Handicap International Belgium’s Road Safety Program Activities and Partnerships

Since 2003, HIB has been implementing a comprehensive road safety programme, which is aligned to the Royal Government of Cambodia’s National Road Safety Action Plan, and activities have been implemented in close collaboration with a variety of government ministries including Public Works and Transport, Interior (Traffic Police), Health and Education, as well as several international and local non-government organizations.

Handicap International’s road safety program has been particularly effective. Actions in this field have included various project, in which the development of the Road Safety Network is remarkably add value of the organization through an encouragement NGOs, companies, schools, hotels,… to develop and implement road safety policy for their workplace.

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\(^1\) Monthly report from January to June 2009, Road Crash and Victim Information System (RCVIS), Handicap International Belgium
The Road Safety Network project builds on these past interventions conducted by HIB with their partners. The project strategy, objectives and activities are all consistent with the National Road Safety Action Plan.

1.3. The Road crash in Cambodia

Following to the RCVIS, reveals that the main causes of road crashes are due to human errors (speeding, drinking and driving, overtaking). Human errors could be overcome, with participation form every road users, organizations, government, companies, communities, and schools. One of the main reasons leading to that because of civil war that took most young people, during decade 70\textsuperscript{th}, involved with fighting and escape from one place to another. Most of them did not attend school but fighting. After the civil war, 1998, they are old and could not attend school. They work as employees in several companies, organizations, or even government ministries. The way they behave on the road is just reflecting what they used to see their parents, friend did before, and they never attend driving school, that's why few people obtain driving license. The report also reveals that only 55\% of drivers involved in the crash have driving license. Figure from the Ministry of Public Works and Transport indicated that less than 20\% of driving license compare with the number of registered vehicles. It is tremendous number of drivers who needs driving license following to the road traffic law. The Cambodia road traffic law suggests every motorbike driver, who drives motorcycle of 49cm\textsuperscript{3} cylinders and up, should hold a driving license.

Motorcycle riders are particularly vulnerable. Motorcycle crashes and casualties represent an alarmingly high percentage of overall crashes and casualties in Cambodia. Almost 77\% of the total number of casualties and 68\% of fatalities involved motorcyles. On the other hand, 34\% of these casualties are between the ages of 15-24 years. The lack of helmet wearing among motorcyclists is a major contributing factor to head injuries. In Cambodia, out of the 19,879 motorcycle casualties in 2008, 93\% were not wearing helmets. As a result, head injuries accounted for 44\% of total injuries.
2. ROAD SAFETY NETWORK

2.1. What is Road Safety Network?
Road Safety Network is a group of NGOs, companies, UN Agencies, schools, factories coming together to promote safe behavior amongst employees and employers via an implementation of road safety policy.

2.2. Objectives
The objective of the project was to encourage organizations and private companies to participate in the improvement of road safety in their work place and community by implementing internal road safety policies and fleet safety management.

2.3. How to Become a Road Safety Network Member?
Any company, organization, school,... that wants to become a Road Safety Network Member should develop and implement the internal Road Safety Policy. The policy should, at least cover the helmet/seatbelt wearing, obtaining driving license for those who drive vehicle, eye examination of drivers, and third party liability (option).

3. METHOD

Method:
The method used in this project was based on practical experience gained from several years working in the field, together with some theories existing in other countries with some adaptations to the context of Cambodia.
Theoretically, amongst the 3Es, this paper is nonetheless focuses only on the Education while Enforcement and Engineering is not involved.

Always Being First in the Market
While majority of adult were never, or very few of them, ever attended driving school, the related work related road crash were high. Only 45% of drivers involved with crash evidence that they possessed proper driving license. The experience showed that many initiatives, especially education awareness would be worthless without any participation from work places, school, and communities. Several activities in the past conducted by HIB have leaded to a small change of behavior. Seeing the opportunity, HIB has developed a new project called “Road Safety Network” that promote as much as possible the organizations, schools, ministries, companies where many adults people work to help promoting the road safety in their work places. With the first initiative, it was a big impression from everyone, even the government. With some high ranking people from government, especially the NRSC representatives showed the event a very high profile.
4. ACTIVITIES

4.1 Launching the project with high involvement of government and companies, NGOs.

- **Development of Road Safety Board Member**
  To ensure adherence to the different organizational and structural principles, the RSN will initially maintain:

  - A **Lead Agency** *(Handicap International Belgium)*, to implement the network, monitor the road safety policies set up by members, accept and reject members and to manage the day-to-day activities of the network.
  
  - A **Coordination Committee (selected members)** to coordinate road safety activities that members implement outside their own organizations. The RSN Coordination Committee is composed of organizations already member of the RSN and implementing road safety activities outside their own organizations. The main roles of the coordination committee are the following:
    - Update on respective road safety activities;
    - Identify overlaps of activities;
    - Suggest coordination mechanisms if necessary;
    - Identify key strengths of each member and find areas for collaboration;
    - Share responsibilities between members if necessary.
  
  The Coordination Committee currently meets **once a month**.

  - An **Advisory Body** *(WHO, MPWT, and MoH)* to provide technical assistance and direction to the network.

The chart below summarizes the structure of the network:

- **Development of the road safety policy**
  The development of the policy is based on the practical information together with the concept of the fleet safety management, which implemented in many countries. The adaptation to the context of the country is necessary. For instance, the driving license and
alcohol test is not widely enforced, but the real situation reveals that only 55% of drivers involved with the crashes has proper driving license to the type of vehicles they were driving. Helmet wearing is not widely applicable in the country. With this case, the development of the policy was developed amongst the NRSC, stakeholders and HIB. The road safety policy is the tool for the companies, NGOs, and others could monitor their employees, and employers to follow the basic road traffic law. The basic requirements of the policy included:

- Helmet/ seatbelt wearing when travel on motorbike or car respectively;
- Obtaining driving license for those who drive, either company car, or individual vehicle that the law require obtaining the driving license;
- Annual eye examination test for those who are drivers of older than 45 years old, with certificate proof from doctor;
- Technical check for those vehicles that belongs to company car or NGOs, or schools;
- Third party liability for those company vehicles (option).

- **Development of awareness materials**

The promotion materials and messages were designed and reviewed by HIB road safety team, and also some consultations with the relevant stakeholders (NGOs, companies, schools). A group of volunteers were recruited and sent for a need assessment and collect all data from those interviewees. Finally, the design of materials was made with some contribution of ideas from several stakeholders, especially those who work for road safety, as well as the NRSC. The production is going along with the theme of the Road Safety Awareness Project within the HIB Road Safety Program. (See sample of road safety policy of one member).

- **Launching the project**

The launching of the project is important, as it would attract the first impression of the potential member of the network. A high profile launching with the presence of the Minister of Public Works and Transport, the officials from the General Secretariat of the NRSC, and officials from the Phnom Penh Municipality is necessary as it showed an impression from the government to the issue. At the same time, the presence of representatives from UN Agencies, WHO, NGOs, companies, and schools to show their involvement in the network.

A full set of preparation of the launching is important. The participants should be preferably human resource manager, executive director, manager, who is able to make the change when they go back.

One week prior to the launching, invitations were sent to all potential members. The invitation addressed to the cause of crashes, the measure that every NGOs, company, schools could contribute to tackle the issue.
Follow the launching, which including of some speeches from the Minister of Public Works and Transports, the Phnom Penh Major representative, the presentation of the network initiative was provided. The presentation, again, highlighted the causes of crashes, the importance of prevention the crashes, and also its affect to the individual who suffered from the crash, the consequences to the institution, and the social as a whole. The presentation provide solution for the audiences to create the internal policy, that suggest everyone in the company, NGO, schools, regardless employees or employers should follow.

At the end of the presentation, a question on weather participant is willing to contribute promoting the road safety in their work place or not. A sample of road safety policy is provided, and as the consequence, some NGOs, companies agreed to develop and implement the road safety policy provided, or some have had the policy merely covered the main important points that the policy suggested.

4.2 What benefit to those are become members of the network?

During the launching, the clear message announced by the chair of the NRSC claimed that every NGOs, school, companies,... participate in the network- developing the road safety policy and implementing the policy would get:
- No cost, but they could ask HIB road safety staff to make a presentation at their work place for free;
- Contribution in helping their employees and employers to act safely on the road;
- A promotion of image of the company in public through a press release at the end of the year. The press release, normally takes place in December every year, provides a list of the Road Safety Network members and printed in a newspaper. The release highlights the importance role of those members in contribution to reduce of road crash in the country;
- HIB would provide one Smiley Logo represent of Road Safety Network Member that they could put in a visible place showing that the company commits to promote road safety amongst their employees, employers and the community they are living.
- Any member could request for a road safety presentation at their work place for free.

4.3 Presentation at work places on Road Safety

A presentation is conducted following the request from member of the network. HIB staff that gets skilled on the road safety issue would conduct the presentation at the work place of the member. The presentation always included with some leaflets, posters for the audiences. Normally, the presentation is a supplement of any monthly or general meeting of the member. The presentation is divided into 3 phases:
- A 15 minutes knowledge test before the presentation. The test was about the road safety issues such as road traffic law, some traffic signs, and some safe behaviors.
- General presentation takes 60 minutes. The general road safety issue includes some statistics of road crash in the world (based on WHO report), number of road injury and fatality in the country (based on number of 10,000 registered vehicle,
100,000 population,...), comparison the road crash between neighbor countries (Vietnam, Laos PDR), comparison amongst age group, gender, type of crash, cost and mainly on causes of road crash (speeding, drinking and driving, right of way rule,..)

- An assessment of the knowledge of the audience and the question and answer session. It is normally the most interest moment of the presentation. Audience could raise questions, recommendation to improve the road safety at their work place, and also to the community, or the country. It is a good chance that they could suggest to government or any involvement bodies to address the issue.

4.4 Increase involvement of members to the road safety issue

Align with the common activity raised by the NRSC, there are two annual events that all members of the network were invited to joint.

- Road Safety Week was held on the first week in April. HIB invited all members to participate in the event. The invitation sent via e-mail and mail. It is a big event of the year to gather all related stake holders and public to come together, in which high government, to provide speech addressing the issue.

- World day of Remembrance for Road Traffic Victims. It is normally falls on third Sunday in November. All members are invited to joint. They were suggested to bring along, as this is very much related to religious ceremony, the foods to offer to the Buddhist monks, in order to remind them of those who died of road crash. The ceremony was followed by the monk chanting and the speech of government representative, and the road crash victim, and also some stakeholders involved with road safety issue.

It is a good chance to promote road safety amongst members by inviting them to joint in public ceremony that related to the road crash.

A press release with list of all members of the network.
5. MONITORING AND EVALUATION FRAMEWORK

Project Preparation Phase
The project preparation phase began from June to July 2004. Key activities within that timeframe were to meet with the relevant stakeholders whose works related to road safety and with the NRSC to seek approval and outline the project objectives and actions. These meetings created the official framework for the implementation of the specific activities.

Project Monitoring and tools
Ongoing project monitoring was regularly provided by HIB through site visits, coordination meetings, and field observation. A bi-monthly meeting amongst board members was to follow up the progress.

For the implementation of the Road Safety Policy amongst members, the site visit by HIB staff was regularly conducted. A staff of HIB meets with manager of the company or event human resource manager in order to access the level of implementation the policy. The tool used for the monitoring is an internal Road Safety Policy developed. Based on this tool, some recommendations were made to the network members for improvement, at the same time there were some suggestions that were taken into account for future activities.

Project Evaluation
To assess the achievement of the project objectives, pre and post test survey were conducted by internal evaluation and then make a comparison to see if there is any progress.

The pretest survey was conducted every time before the presentation to members’ workplaces, and the post-test was conducted from 14 to 30 March 2009. All places where the presentation takes place would be accessed. With an A4 paper that included several questions mainly on knowledge of traffic law, traffic signs, some behaviors on the road, and some tricky questions were suggested to be filled by audiences. A score was given following to the pattern set.

The result showed that the understanding of possessing driving license increased from 36% to 72%; knowledge on eye examination amongst drivers were increased from 36% up to 60%; believing that seatbelt is important increased from 52% to 83%, and helmet wearing rate increased from 63% to 88%. (See table below.)
At the same time, the survey also indicated the number of road safety network member growth from year 2005 to 2008 as below table.

Some of the network members tend to subsidize for the implementation of the internal road safety policy. With graph below, there are 51% of members subsidize helmet for their staffs in 2005 and 2008, while the eye examination and driving license were increase from nil in 2005 to some extend in 2008.

Source: HIB internal evaluation 2008
6. CHALLENGES AND LESSONS LEARNED

The Road Safety Network project presented a few challenges and lessons learned as outlined below:

6.1. Challenges

- One of the project strategies was to collaborate with several stakeholders, who are almost busy with their own activities, and have devote little time for the network;
- There are many obstacles within the collaboration, especially amongst local authorities, most notably the time needed to negotiate through the government’s bureaucratic processes. Activities were delayed several times because of this challenge;
- There is no passenger helmet law in the traffic law. All these factors together lead to a general unwillingness to wear helmets;
- Traffic police did not continuously enforce the road traffic law. As a consequence, some members are neglect to tightening the implementation of the internal policy.
- Some members feel difficult to ask every one to follow the policy, and some of them do not enforce regularly.

6.2. Lessons Learned

The project generated the following lessons learned:

- For the first time, the Road safety Network created in the country. It would be more effective when there is a link with the awareness activity and enforcement;
- It is important to have a clear and unique message states in the road safety policy. The board members could play an important role in dismiss or warn any member did not perform well the policy;
- Collaboration and coordination amongst stake holders is a key to success because all partners were able to share resources and technical expertise, as well as avoid duplication of activities, throughout the project duration;
- An issuing a label to member is a new idea that help encouraging member to implement the policy that benefits to individual member and image of the organization.
- A strict follow-up is crucial, as the member would forget to enforce their staff to follow the policy.

7. CONCLUSIONS

The project was successful in achieving its objective by promoting number of organizations, companies, UN agencies, schools reach the requirement. The knowledge on basic understanding of road safety, attitudes and behaviors of network members’ employees toward helmet wearing rate and possessing driving license increased.
This achievement was largely due to the effective development and implementation of the Internal Road Safety Policy within the network members.

In addition, a key element of the project was a creation of road safety network label, thus increasing the commitment and motivation of the members due they could display their good will in contribution to the reduction of the road crash within their employees and further more the community.

The project was also able to bring a variety of partners together towards a common goal of improving helmet/seatbelt wearing, possessing driving license, promote safe behavior on the road, including the National Road Safety Committee, the Phnom Penh municipality, partner organizations active in road safety, as well as NGOs, companies, schools, UN Agencies. The commitment from all partners became a key strength of the implementation.

The result from all members was positive. This project could be a pilot one and the model proved effective. There is tremendous need to scale-up these initiatives to other places else regardless in any country. Therefore, it is recommended that the Road Safety Network Projects is replicated in other countries to ensure that the widespread high-risk behavior of non-helmet/seatbelt wearing, driving license possession is tackle to reduce injury and fatalities.

REFERENCES:

Monthly report from January to June 2009, Road Crash and Victim Information System (RCVIS), Handicap International Belgium
Make Roads Safe, A Decade of Action for Road Safety, by Commission for Road Safety.
ABSTRACT
The concept of "safety culture" arose in the late 1980s as a consequence of the Chernobyl accident in 1986, and the lack of an adequate safety culture was identified as a major cause of the accidents. An adequate or good safety culture within an organization is characterized by a strong focus and high value on safety; it is part of an organization's "culture". Studies of safety culture have been conducted in a number of organizations and companies faced with potential dangers, although to a limited degree within the transport sector. This study presents the results of surveys conducted in various transport companies in which drivers and pilots were questioned on safety-related issues. The safety culture of different transport modes is compared by using the safety culture index constructed by the Global Aviation Network. Aviation shows to exhibit the best safety culture, followed by rail transport, while bus companies have the poorest safety culture. The results also demonstrate a strong link between safety culture and the work environment and between safety culture and job-related sickness absence. The employees' perception of their company's safety culture influences their own safety behaviour, both within and outside the work environment. The study also shows a close relationship between an adherence to rules and instructions at work and self-reported transport accidents and incidents.

1 INTRODUCTION
There have been many different attempts to define "safety culture" and the concept has been widely debated among researchers and scholars. One fundamental and controversial issue is whether it is even possible to measure safety culture (Haukelid, 2008). In this study, we follow the concept of what James Reason (1997) defines as an understanding of a good safety culture. He identifies five important aspects:

a) Informed culture: The organization collects information about both accidents and incidents, and carries out proactive counter measures by the use of safety audits and surveys on safety climate.
b) Reporting culture: All employees report their errors or near misses, and take part in surveys on safety culture and so on.
c) Just culture: There is an atmosphere of trust within an organization that encourages and rewards its employees for providing information on errors and incidents, with the confidence of knowing that they will receive fair and just treatment for any mistake they make.
d) Flexible culture: The organization has the ability to change its practices.
e) Learning culture: The organization learns from incident reports, safety audits and so forth, resulting in improved safety.

In addition to these characteristics, Reason and others maintain that an organization’s safety culture is tightly bound to its overall culture (Flin, Mearns, O'Connor, & Bryden, 2000; Glendon & Stanton, 2000; Guldenmund, 2000; Haukelid, 2008), and also influenced by
external conditions such as laws and regulations, governmental supervision, market situation and the like. Since an organization’s safety culture is assumed to be part of its general culture, we expect that there will be a close relationship between safety culture and the work environment.

We also expect safety culture to be heavily influenced by structural characteristics/external conditions that vary between transport modes, both because of the rules and procedures governing the different transport modes and because of the different amount of supervision and support. Pilots have specialized skills and to some extent are held in high esteem. They typically have strong support systems in terms of both technology and services (e.g. weather services, air traffic controllers) whereas bus drivers may have the lowest esteem and least amount of supervision and support.

These differences also influence the degree to which formal safety systems are at place (HES procedures, training, maintenance etc.) and we expect that the presence of such formal safety systems influence the safety culture within an organization cf. Figure 1. It is also assumed that the safety culture influences the attitude and behaviour of employees towards safety, which is reflected in their safety records.

In the present study we want to compare safety culture between transport modes. We also want to investigate whether transport companies having a good safety culture according to their employee’s perceptions also exhibit fewer accidents than others. Furthermore, are single employee’s who consider the safety culture to be good less at risk than employee’s who do not feel the same about their company’s safety culture? And does a good safety culture at work also influence employee’s safety attitudes and behaviours in their free time – something that could be expected if employees internalize safety culture values. Finally, we also look into possible relationships between safety culture, work environment and sickness absence.

The research questions will be answered by use of a questionnaire to employees’ in different transport companies, covering road rail and air transport. Figure 1 gives an outline of the expected relationships between the different elements/variables.

![Figure 1: A model of the relationships between safety culture and other factors.](image-url)
The link between “Management’s focus on safety” and safety culture, will however not be tested independently because this is in many ways incorporated in the safety culture questions. Many of the questions about safety culture in the questionnaire are questions about managers’ attitudes and focus on safety issues.

2 METHOD

2.1 Sample
The sample consists of pilots in Norwegian/Scandinavian airline and helicopter companies, bus drivers in two different Norwegian bus companies and tram and underground drivers in Oslo. Safety culture questions were included as a part of surveys conducted in the various transport companies (three airline companies, two helicopter companies, two bus companies and two rail companies). All respondents were drivers, i.e. pilots, rail or bus drivers, who received the same safety culture questions. For rail and bus drivers, the surveys also included questions about work environment. Questionnaires were distributed to airplane and helicopter pilots in 2005 and to bus and rail drivers in 2006. The number of respondent in the net sample and the response rates are given in table 1.

Table 1: The net sample distributed by transport mode. Numbers and response rates.

<table>
<thead>
<tr>
<th>Transport Mode</th>
<th>Sample (N)</th>
<th>Response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane</td>
<td>585</td>
<td>44.5</td>
</tr>
<tr>
<td>Helicopter</td>
<td>71</td>
<td>37.2</td>
</tr>
<tr>
<td>Bus</td>
<td>514</td>
<td>74.5</td>
</tr>
<tr>
<td>Rail</td>
<td>237</td>
<td>36.2</td>
</tr>
<tr>
<td>Total</td>
<td>1407</td>
<td>49.9</td>
</tr>
</tbody>
</table>

2.2 Questionnaire
Attempts to measure and quantify safety culture have traditionally been accomplished by the use of surveys. These surveys have normally been very closely oriented towards the specific activities within the organization in question, thus hampering the possibility of comparing safety cultures between different sectors or trades. However, there have been attempts within the aviation industry to construct a more general and less activity-specific safety culture (climate) survey, so as to make precise comparisons across various types of organizations and activities possible (Isla Díaz & Díaz Cabrera, 1997).

We have chosen to use one such questionnaire developed by the Global Aviation Network (GAIN). (GAIN, 2001) This questionnaire consists of 25 safety-related questions covering five presumably safety-relevant issues: 1) Management’s attitude and focus on safety; 2) The attitude and focus on safety among employees; 3) Culture of reporting and reactions to reported errors and incidents; 4) Safety training and education; and 5) General questions about safety within the organization.

The respondents answered all questions using a scale from 1 (disagree completely) to 5 (agree completely) cf. Appendix 1. One question (no. 12) was omitted due to the fact that the question’s wording was unfamiliar to rail and bus drivers. Questions regarding the work environment are to a large extent questions from “The General Nordic questionnaire for psychological and social factors at work” (QPS-Nordic) (Skogstad, et al., 2001).
2.3 Variable specifications and statistical analyses

In order to investigate the proposed relationships in the model in figure one, we need to specify the variables to be analyzed.

Safety culture is measured by use of a safety culture index computed as the sum score of all questions about safety culture. Given the fact that one question was omitted our safety culture index has a maximum score of 120 (24 x 5) and a minimum score of 24 (24 x 1).

The structural characteristics/external conditions depicted in the top box in figure 1 are not specified as variables. We assume that these characteristics constitute the main differences between the different transport modes covered in the sample. Thus if safety culture index values vary systematically between the different transport modes we interpret this as mainly an effect of different structural characteristics/external conditions.

“Formal safety systems” are measured by the following three variables: i) the degree to which employees know who to contact on HES issues (HES-contact) ii) the degree to which employees are given tasks without adequate training (Training), and iii) the degree to which the driver experiences stress because of insufficient maintenance of the vehicle (Maintenance).

HES-contact is based on answers to the question: Do you know who to contact on issues concerning a) work hours, b) health, insecurity and stress, c) vehicle operation, errors, incidents and accidents, d) physical issues concerning the work environment (noise, ventilation, comfort etc.). The answer alternatives were: 1) Yes, absolutely sure, 2) Yes, pretty sure, 3) Not sure, 4) No. Based on these combinations a sum-score index was computed. High values on the HES-contact index correspond to high degrees of certainty about who to contact.

Adequate job training was measured by the question: “How often do you experience insufficient training for the task you are set to do?” Respondents were to answer on a scale from “Very seldom/never” (1) to “Very often/always” (5). Maintenance stress was measured by a Likert scale varying from “agree totally” (1) to (5) “disagree totally”. When entered into the models, the order of the values has been reversed on the variables Training and Maintenance, so that high values correspond to adequate training and low stress about maintenance.

Individual safety attitude and behaviour at work was measured by the following question: “If you bend rules and procedures, what are the reasons for doing so?” Respondents could chose between eight answer alternatives, the first: “It doesn’t happen” (that I bend the rules) and then seven possible reasons for bending the rules. It was possible to give more than one answer to the question. Those who answered that they never bend the rules were given value 1 on the variable “Rule following” (56.2 per cent) and those who bend the rules for some reason(s) were given the value 0 (43.8 per cent).

We hypothesized that safety culture at work also could influence employees’ safety behaviours in their free time. Three different questions were included to measure this: a) “How often do you buckle the seat belt in the back seat of taxis” (Seat belt), b) “How often do you maintain speed limits when driving a car” (Speed limit) and c) How often do you pay attention to safety demonstrations on air flights? On all three questions respondents were to answer on a scale from “Very seldom/never” (1) to “Very often/always” (5).

We use two questions to measure different aspects of the work environment. The first was the assertion “There is good cooperation in the work environment”; the second was “Generally I enjoy my work”. Answers were to be scored on a five-point scale from “completely agree” to “completely disagree”. Most respondents (around 80 per cent) agreed to the assertions so that in order to have variables with sufficient variation, we computed two dummy variables (WorkEnv and EnjoyWork) where those who agree completely (39 per cent and 46 per cent respectively) are given the value 1 and all others are given the value 0.
Sickness absence was measured by a dummy variable based on self-reported absence due to job-related sickness. The question was: “Have you been absent from work because of job-related sickness during the last year?” This was given to all respondents. Those having been absent due to job-related sickness (18.8 per cent) were given value 1 on the variable “Sickness absence”, the others were given value 0.

Finally, actual safety was measured by the question: “Have you been involved in accidents or serious incidents as bus/train/tram driver during 2005/2006?” (not given to helicopter and aviation pilots). A dummy variable was constructed were those who had one or more accidents/incidents were given the value 1 (39.2 per cent) and those without got the value 0 (61.8 per cent).

In addition to the variables specified to test the relationships in the model in figure 1 we have included gender (male=1, female=2), age (1=<25 years, 2=25-34 years, 3=35-44 years, 4=45-54 years and 5=≥55 years), number of years employed in the company (YearEmp (1=<5 years, 2=5-10 years, 3=11-15 years, 4=>15 year)) and transport mode (Rail: bus=0, rail=1) as independent control variables.

In order to investigate into the assumed causal relationships between safety culture, individual attitudes and behaviours, work environment, safety and sickness absence, we have used analyses of variance and linear and logistic regression models. Regression models including work environment variables are restricted to bus and rail drivers due to the lack of such data for aviation. The statistical analyses have been conducted by use of SPSS.

### RESULTS

#### 3.1 Safety culture index scores

A one-way analysis of variance (ANOVA) shows that helicopter pilots achieved the highest mean score on the safety culture index followed by airline pilots and rail drivers. Bus drivers exhibited the poorest safety culture according to this measurement. The differences were statistically significant at the p<0.5 level for the four different transport modes (F(3, 1403)=.000). The effect size, calculated using eta squared was .07 which may be considered a medium size effect (Cohen, 1988).

Table 2: Mean scores on the safety culture index distributed by transport modes.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bus</td>
<td>514</td>
<td>80.06</td>
<td>15.98</td>
</tr>
<tr>
<td>Rail</td>
<td>237</td>
<td>83.55</td>
<td>15.53</td>
</tr>
<tr>
<td>Airline</td>
<td>585</td>
<td>88.68</td>
<td>14.24</td>
</tr>
<tr>
<td>Helicopter</td>
<td>71</td>
<td>90.99</td>
<td>12.24</td>
</tr>
<tr>
<td>Total</td>
<td>1407</td>
<td>84.78</td>
<td>15.56</td>
</tr>
</tbody>
</table>

Post hoc comparisons using the Tukey HSD test indicated that the mean score for bus is significantly different from all the other transport modes (p<.05); the mean score for rail is in addition statistically different from the mean scores of airlines and helicopters. The mean difference between airline pilots and helicopter pilots is however not statistically significant. The differences in mean values on the safety culture index are as expected, and correspond to actual differences in accident risk between the different transport modes (Elvik & Bjørnskau, 2005; Elvik & Vaa, 2004).

The differences in safety culture index values probably reflect different external conditions that characterize the various transport modes. Aviation has traditionally had a very strong
focus on safety, which is strongly regulated by international treaties. In Norway, rail transport also has a strong safety focus, with strict national safety regulations and a separate supervisory authority. Bus transport, being part of the road transport system, is not subject to similar safety regulations in Norway. The expected link between structural characteristics and safety culture given in figure 1 is accordingly supported by the analysis.

3.2 Effects of HES-procedures on safety culture
In figure 1 there is an expected link between Formal safety systems and safety culture procedures. Table 3 gives the results of a standard linear regression model with the safety culture index as dependent variable and HES-contact, Maintenance and Training as independent variables. Also Gender, Age, YearEmp and Rail are entered as independent variables. As mentioned, only rail and bus drivers have been given the questions about work environment issues so the analysis is restricted to these types of drivers.


<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Beta</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>86.380</td>
<td>2.866</td>
<td></td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YearEmp</td>
<td>-2.015</td>
<td>.441</td>
<td>-.152</td>
<td>.000</td>
</tr>
<tr>
<td>Rail=1</td>
<td>3.210</td>
<td>1.139</td>
<td>.095</td>
<td>.005</td>
</tr>
<tr>
<td>HES-contact</td>
<td>2.009</td>
<td>.191</td>
<td>.355</td>
<td>.000</td>
</tr>
<tr>
<td>Maintenance</td>
<td>2.204</td>
<td>.445</td>
<td>.172</td>
<td>.000</td>
</tr>
<tr>
<td>Training</td>
<td>1.319</td>
<td>.524</td>
<td>.086</td>
<td>.012</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td><strong>0.22</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With the Forward method used, SPSS includes those of the specified independent variables that contribute significantly to the variation in the dependent variable. There are statistically significant effects of all three variables entered to measure the effects of formal safety systems and in the expected direction. The better the knowledge of whom to contact about HES-issues, the better is the score on the safety culture index. The same is true for “Maintenance” and “Training” but the effects are weaker, cf. the Beta values. The differences between the B and Beta values reflect the number of values on the different variables; HES-contact is an index with 16 values whereas Maintenance and Training only have five values.

There are no significant results for gender and age, but a negative effect of YearEmp, i.e. the longer the job experience in the company the lower the score on the safety culture index. The model explains 22 per cent of the variance in the dependent variable (R² = .22) which must be considered as a reasonable good fit.

3.3 Effects of safety culture on individual attitudes and behaviours
In order to test the influence of safety culture on Rule following we applied logistic regression analysis with Rule following as dependent variable and safety culture, age, gender, rail, HES-contact, Maintenance and Training as independent variables.

We adopt the “forward stepwise method (FSTEP) which is similar to the “Forward” method of linear regression, i.e. SPSS includes the specified independent variables that contribute significantly to the variation in the dependent variable. Results are given in table 4. As indicated in our model in Figure 1, safety culture has a major effect on individual rule following (Wald=46.28). The Exp (b) = 1.037 tells us that on average, when the safety culture
index is increased by one, the likelihood (odds) of belonging to the group that never bends the rules increases by a factor of 1.037.

Table 4. Logistic regression. Rule following as dependent variable. Method: FSTEP

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std Error</th>
<th>Wald</th>
<th>Sig</th>
<th>Exp (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.483</td>
<td>.517</td>
<td>45.45</td>
<td>.000</td>
<td>0.031</td>
</tr>
<tr>
<td>YearEmp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail=1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HES-contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>.192</td>
<td>.078</td>
<td>6.022</td>
<td>.014</td>
<td>1.212</td>
</tr>
<tr>
<td>Safety culture</td>
<td>.037</td>
<td>.005</td>
<td>46.28</td>
<td>.000</td>
<td>1.037</td>
</tr>
</tbody>
</table>

Nagelkerke $R^2 = 0.114$

Training has also a positive and significant influence on Rule following. None of the other independent variables contribute significantly and the overall explained variance is modest (Nagelkerke $R^2 = 0.114$).

Table 5 gives the results of three linear regression models with “Safety demo” “Seat belts” and “Speed limits” as dependent variables and the same independent variables included as in table 4. In addition “Rule following” is now included as an independent variable. For ease of presentation standard errors of the coefficients are omitted from table 5

Table 5. Standard linear regression (OLS). Dependent variables = Safety demo, Seat belts and Speed limits. Method=Forward.

<table>
<thead>
<tr>
<th></th>
<th>Safety demo</th>
<th>Seat belts</th>
<th>Speed limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Beta</td>
<td>Sig</td>
<td>B</td>
</tr>
<tr>
<td>Constant</td>
<td>3.259</td>
<td>.000</td>
<td>2.164</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.093</td>
<td>.084</td>
<td>.028</td>
</tr>
<tr>
<td>YearEmp</td>
<td>-.443</td>
<td>-.161</td>
<td>.000</td>
</tr>
<tr>
<td>Rail=1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety culture</td>
<td>.271</td>
<td>.103</td>
<td>.006</td>
</tr>
<tr>
<td>Rule following</td>
<td>.088</td>
<td>.084</td>
<td>.026</td>
</tr>
<tr>
<td>HES-contact</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>.088</td>
<td>.084</td>
<td>.026</td>
</tr>
</tbody>
</table>

$R^2 = .055$  \(.029\)  \(.021\)

Age, Rail, Rule following and Maintenance contribute significantly to the attention people pay to safety demonstrations on air flights. Age contributes positively, i.e. older people pay more attention than younger. Rail drivers pay less attention than bus drivers. Those who follow rules at work pay significantly more attention to safety demonstrations than those who do not always follow rules at work. They also buckle the seat belts in taxis to a greater extent than those not always following the rules. Finally, those who are more confident about the technical maintenance at work pay more attention to safety demonstrations on air flights and buckle up in the back seats of taxis to a greater extent than those who are more worried about technical maintenance.
The explained variance $R^2$ is low in all three models. The models are however all significant and they give some support to the hypothesis that safety culture influence safety behavior also in the free time. However this effect goes primarily through the variable Rule following which we saw was heavily influenced by safety culture (cf. table 4). In a similar model (not shown here) where Rule following, Maintenance and Training are omitted, safety culture contributes significantly on attention to safety demonstrations on air flights.

### 3.4 Effects of safety culture on work environment, sickness absence and safety

According to the model in figure 1, we expect a relationship between safety culture and work environment, sickness absence and traffic safety, mainly through individual safety attitudes and behaviours. We also expect a direct effect from Formal safety systems to work environment/sickness absence and actual safety. Although we expect safety culture primarily to influence work environment/sickness absence and safety through individual attitudes and behaviours, it is of interest to look into possible bivariate relationships between safety culture and these variables.

#### 3.4.1 Safety culture and work environment

Table 6 gives the results of two logistic regression models with WorkEnv and EnjoyWork as dependent variables and the same independent variables as in table 5.

<table>
<thead>
<tr>
<th>Method: FSTEP</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sig</th>
<th>Exp (b)</th>
<th>B</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sig</th>
<th>Exp (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-2.2</td>
<td>1.22</td>
<td>12.4</td>
<td>.000</td>
<td>.111</td>
<td>-3.0</td>
<td>1.36</td>
<td>21.7</td>
<td>.000</td>
<td>.052</td>
</tr>
<tr>
<td>YearEmp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender Rail=1</td>
<td>.210</td>
<td>.036</td>
<td>34.0</td>
<td>.000</td>
<td>1.23</td>
<td>.199</td>
<td>.035</td>
<td>32.4</td>
<td>.000</td>
<td>1.22</td>
</tr>
<tr>
<td>HES-contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>.217</td>
<td>.075</td>
<td>9.1</td>
<td>.003</td>
<td>1.24</td>
<td>.217</td>
<td>.075</td>
<td>9.1</td>
<td>.003</td>
<td>1.24</td>
</tr>
<tr>
<td>Safety culture</td>
<td>.038</td>
<td>.006</td>
<td>36.7</td>
<td>.000</td>
<td>1.04</td>
<td>.039</td>
<td>.006</td>
<td>37.0</td>
<td>.000</td>
<td>1.04</td>
</tr>
<tr>
<td>Rule following</td>
<td>.460</td>
<td>.174</td>
<td>7.0</td>
<td>.008</td>
<td>1.59</td>
<td>.460</td>
<td>.174</td>
<td>7.0</td>
<td>.008</td>
<td>1.59</td>
</tr>
</tbody>
</table>

According to table 6 there are statistically significant relationships between HES-contact and Safety culture and the two dependent variables. Thus the effect of safety culture on the work environment is not only through individual attitudes and behaviours as depicted in figure 1. There are also significant effects of Maintenance and Rule following on the variable “EnjoyWork”. The model fits are reasonable with Nagelkerke $R^2$ of .205 and .275.

There is a quite substantial effect of safety culture index scores the two variables WorkEnv and EnjoyWork (WALD=36.7 and 37.0). In order to illustrate the relationship between safety culture and the work environment a bivariate relationship between safety culture and self-reported job satisfaction is given in figure 2.
A two-way analyses of variance (ANOVA) shows highly significant effects of job satisfaction on safety culture \([F(4, 735) = 40.5 \ p = .000]\), Eta squared = .18. The main effect for transport mode did not reach statistical significance \([F(1.735) = 1.8 \ p = .93]\). There is no interaction effect. Post-hoc comparisons using the Tukey HSD test indicated significant mean differences between those who completely agree and every other group, and also between those that mostly agree and every other group. No other mean difference is statistically significant.

### 3.4.1 Safety culture and sickness absence

Questions about sickness absence due to factors at work were given to all respondents, also helicopter and airline pilots. The bivariate relationship between safety culture and sickness absence are given in figure 3 for each transport mode.

A two-way analyses of variance (ANOVA) shows highly significant links both between transport modes and safety culture \([F(3. 1383) = 13.1 \ p = .000]\) and between sickness absence and safety culture \([F(1. 1383) = 20.5 \ p = .000]\). The effect sizes are however small, (partial eta squared = .03 and .02 respectively). There was no significant interaction effect. Post-hoc comparisons using the Tukey HSD test indicated significant mean differences between the transport modes except between airplane and helicopter. A logistic regression model with sickness absence as dependent variable and the same independent variables entered as in table...
6 is presented in table 7. Note again that the regression model is restricted to bus and rail drivers due to the lack of work environment data for aviation.

Table 7. Logistic regression models with sickness absence as dependent variable. 
Method: FSTEP

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sig</th>
<th>Exp (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.75</td>
<td>.530</td>
<td>10.88</td>
<td>.001</td>
<td>5.75</td>
</tr>
<tr>
<td>YearEmp</td>
<td>-.269</td>
<td>.079</td>
<td>11.67</td>
<td>.001</td>
<td>.764</td>
</tr>
<tr>
<td>Age</td>
<td></td>
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<tr>
<td>Gender</td>
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<td></td>
</tr>
<tr>
<td>Rail=1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HES-contact</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety culture</td>
<td>-.026</td>
<td>.006</td>
<td>20.53</td>
<td>.000</td>
<td>.974</td>
</tr>
<tr>
<td>Rule following</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nagelkerke $R^2 = .068$

Only Safety culture and Age influence the sickness absence according to the model in table 7. There is a negative effect of age, i.e. young employees are more absent due to sickness than older employees. Safety culture has the expected effect, given the results showed in figure 3; the better people perceive the safety culture to be, the less absent they are due to job-related sickness. The effect of Safety culture is substantial ($Wald=20.53$), but the overall fit is modest ($Nagelkerke R^2 = .068$).

3.5 Safety culture and safety

Finally, in order to measure the relationship between safety culture and actual safety, a logistic regression analysis was conducted with self-reported accidents/incidents as dependent variable and the same independent variables as in table 7. Results are given in table 8.

Table 8. Logistic regression models with accident/serious incident as dependent variable. 
Method: FSTEP

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Error</th>
<th>Wald</th>
<th>Sig</th>
<th>Exp (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>.391</td>
<td>.179</td>
<td>4.77</td>
<td>.029</td>
<td>1.478</td>
</tr>
<tr>
<td>YearEmp</td>
<td>-.32</td>
<td>.069</td>
<td>21.62</td>
<td>.000</td>
<td>.727</td>
</tr>
<tr>
<td>Age</td>
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<tr>
<td>Gender</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Rail=1</td>
<td></td>
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<tr>
<td>HES-contact</td>
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<tr>
<td>Maintenance</td>
<td></td>
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</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety culture</td>
<td>-.314</td>
<td>.156</td>
<td>4.05</td>
<td>.044</td>
<td>.730</td>
</tr>
<tr>
<td>Rule following</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Nagelkerke $R^2 = .048$

Only YearEmp and Rule following contribute significantly to the variation in the odds of having had accident/incident. The likelihood (odds) of having had an accident or serious incident declines with experience, a result that corresponds well with numerous risk studies in road safety research (Elvik & Vaa, 2004). Also Rule following contribute significantly to the
likelihood of having had an accident or serious incident. The other independent variables do not contribute, and the explained variance is low (Nagelkerke $R^2 = .048$).

There is no significant effect of Safety culture in table 8. More detailed analyses show however that safety culture co-varies with incidents/accidents in a non-linear fashion. It seems that those drivers who have reported one incident or accident are the ones who perceive the safety culture to be best, as opposed to those who have had no reported incidents or two or more accidents/incidents.

4 REVISED MODEL BASED ON THE RESULTS

In figure 4 we present a revised version of the model depicted in figure 1 that sums up the results of our analyses. The model now contains the specified variables used in the analyses and links between variables that have been tested and received supported empirically are indicated by the thick arrows.

![Diagram](image.png)

Figure 4. Revised model of the relationships between safety culture and other factors.

5 DISCUSSION

5.1 The model is generally supported by the data

Not surprisingly, aviation pilots achieved the highest score on the safety culture index followed by rail drivers. Bus drivers exhibited the poorest safety culture in this study, cf. figure 2. These results are very much as expected, and in many ways can be seen to reflect the different external conditions of the various transport modes.

In the model in figure 1 it was assumed that the presence of formal systems for health, environment and safety issues (HES systems) are positively associated with safety culture. Regression models show a strong link between the safety culture index scores and questions concerning the knowledge of who to contact in regard to different HES issues. There are also indications that those who worry about insufficient technical maintenance perceive the safety culture as being worse when compared to those who do not worry about technical maintenance.
The analyses show a strong relationship between safety culture index scores and an adherence to rules and instructions at work. Those with high scores on the safety culture index perceive the safety culture within their organization to be good, and show a much stricter adherence to the rules and instructions than those who perceive the safety culture to be poor. There are also clear links between adhering to rules and instructions at work and behaving in accordance with safety rules outside work. Those who adhere to the rules and instructions at work buckle their seat belts in the back seats of taxis, pay attention to safety demonstrations on air flights, and maintain the speed limit while driving as compared to those who do not adhere to these same rules and instructions.

Those who report a good safety culture within the organization where they work also tend to report a good work environment and greater job satisfaction. There are also clear indications that possessing the knowledge about who to contact in HES issues is positively associated with the perception of a good work environment and job satisfaction.

5.2 No clear relationship between safety culture and accidents/incidents

One surprising result is that we find that those drivers who have reported one incident or accident are the ones who perceive the safety culture to be best, as opposed to those who have had no reported incidents or accidents. There are several probable reasons for this perhaps surprising result. First, one has to remember that the questions about safety culture all concern how a single employee perceives the general safety culture in their company, and are not about his/her own behaviour. We do find a close link between one’s personal behaviour (Rule following) and incidents and accidents, although not between an individual’s perception of safety culture and their safety record.

Second, a key element of a good safety culture is that employees trust management to the point that they are willing to report their own errors and incidents. This is undoubtedly an important reason for the test results; those who perceive the safety culture to be good are precisely the ones who dare to report their incidents.

Third, it is also possible that those who have had a serious incident or accident have found that management had treated them fairly, and focused on finding the true causes behind the incident. Accordingly, drivers who experienced accidents or incidents may perceive the safety culture as better than those who had not had any accidents or incidents precisely because of this experience of fair and just treatment after the incident or accident.

All these different explanations may be true, which indicates that the relationship between safety culture and actual safety should preferably be analysed by the use of register data, and not by self-reported incidents and accidents, although this is difficult to accomplish in transport modes with few accidents.

6 CONCLUSION

The assumed relationships in the model generally received empirical support. However, the relationship between safety culture and actual safety is complicated and difficult to test by using self-reported incidents and accidents. Nevertheless, it is possible to study the relationship on an aggregate level – and we do find, as expected, that safety culture varies between transport modes in accordance with actual risk differences.

It would also be possible to study how safety culture relates to actual safety between companies within one transport mode, if all accidents were registered in the same way. One possibility, for instance, would be to study such relationships in road transport between bus companies or with other firms in a given transport mode.

Organizational factors such as safety culture have not traditionally been focused on in road safety analyses. The close links between safety culture, work environment, individual safety behaviour, and incidents and accidents indicate that efforts to improve safety culture show a
great potential for increasing transport safety. The results also indicate that an improvement in safety culture may yield both a better work environment and less sickness absence from work.

7 REFERENCES
APPENDIX
The GAIN safety culture questionnaire:

1. Employees are given enough training to do their tasks safely
2. Managers get personally involved in safety enhancement activities
3. There are procedures to follow in the event of an emergency in my work area
4. Managers often discuss safety issues with employees
5. Employees do all they can to prevent accidents
6. Everyone is given sufficient opportunity to make suggestions regarding safety issues
7. Employees often encourage each other to work safely
8. Managers are aware of the main safety problems in the workplace
9. All new employees are provided with sufficient safety training before commencing work
10. Managers often praise employees they see working safely
11. Everyone is kept informed of any changes, which may affect safety
12. Employees follow safety rules almost all of the time
13. Safety within this company is better than in other airlines
14. Managers do all they can to prevent accidents
15. Accident investigations attempt to find the real cause of accidents, rather than just blame the people involved.
16. Managers recognise when employees are working unsafely
17. Any defects or hazards that are reported are rectified promptly
18. There are mechanisms in place in my work area for me to report safety deficiencies
19. Managers stop unsafe operations or activities
20. After an accident has occurred, appropriate actions are usually taken to reduce the chance of recurrence.
21. Everyone is given sufficient feedback regarding this company’s safety performance
22. Managers regard safety to be a very important part of all work activities
23. Safety audits are carried out frequently
24. Safety within this company is generally well controlled
25. Employees usually report any dangerous work practices they see
AN INNOVATIVE APPROACH TO ADDRESSING HEAVY VEHICLE SAFETY

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ABSTRACT
Lowering the road toll remains a key objective for developed nations including the United Arab Emirates (UAE), where regulators are presently undertaking many initiatives aimed at addressing the road safety issue. However, heavy vehicle operations remain largely unregulated. This has the potential to pose considerable road safety risks for a federation where the freight transport task is predominantly undertaken by this mode of transport.

Australia’s innovative performance-based approach to addressing heavy vehicle safety is representative of worldwide best-practice in this field. The Australian method uses defined performance requirements in critical safety areas including high-speed dynamic behaviour and roll stability of vehicles, and assesses compliance with these requirements via computer simulation techniques. This method generally permits longer and heavier vehicle combinations to be operated than those allowed under traditional prescriptive regulations, which has the end result of increasing efficiency without detriment to safety.

Using this method, ARRB Group Ltd has recently completed a project which assessed the performance of representative vehicles from Europe, North America, South Africa and Australia. This paper discusses the applicability of a similar approach for the UAE to assess typical transport vehicles, and guide future policy on weight, dimension limits and access arrangements.
1 INTRODUCTION

Among developed and developing nations, the various Emirates comprising the UAE continue to report high road accident crash rates. As an example, the Health Authority of Abu Dhabi (HAAD) reports that Abu Dhabi has one of the highest road traffic fatality rates in the world, at 27.1 deaths per 100,000 population (HAAD, 2007). This rate is much higher than that of Australia, the European Union, and the USA (9.5, 11.0, and 15.2 deaths per 100,000 population respectively), and at the upper end of countries within the broad African region (between 19.1 – 28.3 deaths per 100,000 population) (WHO, 2004). In an effort to address this trend, various road safety activities have been launched in the UAE in recent times and promoted heavily by local road safety authorities.

These campaigns and initiatives predominantly focus on addressing the major crash and injury causes that have been identified by recent studies. These causes include reckless driving, particularly speeding and tailgating, failing to wear seat belts and violating road rules and traffic signals such as red lights. Addressing attitudinal and behavioural issues such as these are clearly the highest priorities for authorities and regulators, but as these campaigns succeed in achieving road safety goals, the focus of attention will shift to other key areas to further reduce the road toll.

The contribution of heavy vehicles to road safety statistics should become one of these key areas, and has been heavily investigated in Australia, Europe, and the Americas over the most recent several decades, but has received little attention to date within the UAE. One recent local study conducted by Abdalla (2002) aimed to identify key crash risk factors which made drivers in the UAE more likely to be involved in crashes than drivers in other countries. Abdalla used fatality and injury data from Dubai police reports, and showed that drivers of light and heavy goods vehicles in the UAE were much more likely to be responsible for causing an accident than drivers from the other study areas. In particular, drivers of heavy goods vehicles from the UAE were five times more likely to cause an accident when compared to the other study areas, and therefore presented a higher crash risk.

In addition, heavy vehicle overloading appears to be prevalent within the UAE. El-Qutob and Sharif (2003) conducted a study of vehicle axle loads based on information collected from several weighing stations in Abu Dhabi across a six-month period, and found that the percentage of overloaded trucks consistently exceeded 90%, and in some instances trucks were sufficiently overloaded to cause damage to the weighing equipment. Overloading vehicles can decrease the stability and performance of the vehicle significantly with relatively low axle weight increases. Overloaded axle groups will also damage road pavements at a much faster rate than conventional axle loads, which may eventually create an unsafe road surface.

Considering the strong reliance of the economies of the UAE on heavy vehicle freight and the dominance of this freight mode within the region, the role of heavy vehicles in road safety is worthy of careful consideration. In this regard, the UAE are in a good position to benefit from the experience of other nations, particularly Australia’s innovative approach to assessing and regulating heavy vehicles, which is considered to represent world-wide best-practice in this field. This approach was recently adapted by ARRB Group Ltd (ARRB) to comparatively assess the performance of typical heavy vehicles from Europe, North America, South Africa and Australia.
This paper provides more information on Australia’s system of regulation and the comparative assessment project, and discusses the applicability of similar approaches for the UAE in assessing heavy vehicles. To provide a useful context for this discussion, the underlying reasons why heavy vehicles are a road safety issue should be understood. Abdalla reasoned that higher risk factors were due to their larger size and longer braking distances. While these factors are a key aspect of the overall issue, more factors are involved than these alone.

2 HEAVY VEHICLES AND ROAD SAFETY
While the heavy vehicle factors which influence road safety are many and varied, much research has been conducted into understanding these factors, which has led to clear quantification and definition. Further to the key factors identified by Abdalla, the increased mass of heavy vehicles not only increases braking distances, but also increases the severity of the consequences of crashes due to the energy and inertia involved, both of which are the products of mass and velocity. As mass increases, energy and inertia also increase, placing high demands on braking systems, and exacerbating negative outcomes when crashes occur.

The high-speed dynamic behaviour of heavy vehicles, particularly articulated vehicles such as semi-trailers, is another critical issue. The trailers of these vehicles can demonstrate a tendency to ‘amplify’ inputs made by the driver through the steering wheel, or to the vehicle through road surface irregularities, which can result in considerable lateral off-tracking or ‘sway’ of following trailers at high speeds, as depicted in Figure 1.

![Figure 1: Plan view of multi-unit vehicle demonstrating the effects of steer input amplification and sway.](image)

This behaviour can present a safety issue for other road users, particularly passing or overtaking vehicles, and may cause the vehicle to crash if the level of sway is sufficiently severe to cause the wheels of one side of the trailer to leave the paved road surface. Dynamic behaviour is also a concern for vehicles transporting a liquid product, as the liquid may ‘slosh’ inside the tank if not sufficiently constrained by compartments, which can result in adverse and often unpredictable dynamic behaviour.

Vehicle engine performance is another key road safety factor. Under-powered vehicles can create potentially hazardous situations, particularly where long or steep grades are involved, as there is likely to be a large speed differential between heavy vehicles and other road users, (such as passenger cars, which are generally capable of maintaining higher speeds). This can result in unsafe behaviour such as attempts to overtake the vehicle in unsuitable locations.

Perhaps the most critical safety concern for rigid and articulated vehicles is their propensity to rollover. The majority of errant passenger vehicles (with the exception of large
four-wheel-drives and vans) are unlikely to experience rollover while travelling on flat, high friction surfaces. Heavy vehicles however, due predominantly to the relationship between centre of gravity height and track width, can experience rollover if subject to sufficiently high lateral forces, such as during typical transient manoeuvres such as swerving to avoid objects, and steady-state manoeuvres such as cornering at high speed. This factor alone renders heavy vehicles a significant road safety risk. The quantifying measure between lateral force and rollover risk is known as the ‘static rollover threshold’ (SRT), which refers to the level of lateral acceleration that a vehicle or trailer can sustain without experiencing rollover.

Mueller et al. (1999) conducted a study into the influences of heavy vehicle stability on crash rates, and reported an increasing trend of rollover risk with decreasing SRT, as shown in Figure 2. The figure refers to the recommended minimum SRT value of 0.35 g (SRT is expressed in units of gravity, where 1 g is an acceleration of 9.807 m/s$^2$), adopted by Australian and New Zealand regulators. This value corresponds to a relative crash rate of approximately 2.5, however it is clear that higher SRT values are more beneficial in terms of safety.

![Fleet Rollover Rate](image)

Figure 2: Relative crash rate vs. static roll threshold (Source: Mueller, 1999)

The influence of overloading on vehicle safety is a critical concern when considered in the context of these results. Overloaded vehicles often have much lower roll thresholds than under-loaded vehicles, due to the effects of adding mass at height, which increases the overall centre of gravity height of the vehicle and/or trailer. Additionally, overloading vehicles increases the demand placed on critical components such as the suspension, brakes, tyres and the vehicle’s chassis, each of which can demonstrate adverse performance if subjected to loads out of their design range, and can even suffer complete failure in severe circumstances.

While there is little published work regarding the prevalence of overloading or increased axle loads of heavy vehicles within the UAE, published work by El-Qutob and Sharif (2003), as well as anecdotal information, indicates that it is widespread and common local practice, a problem which is perhaps magnified by the lack of guidance and enforcement regarding
correct axle loading policy. In the UAE in 1986, Federal Law Number 8 was enacted, specifying limits for heavy vehicle loads and dimensions, but the law was not immediately enforced due to the lack of appropriate measuring equipment and vehicle monitoring facilities, and it is anticipated that many vehicles presently operate with high axle loads.

In the context of this information, the case for clearly defined and diligently enforced heavy vehicle regulation is strong, and within this, ensuring adherence to axle load limits should be considered a key priority, as this has great influence on vehicle operational safety and overall crash risk. Regulators in both Abu Dhabi and Dubai have recently undertaken programs to monitor or enforce axle load limits. However, the question remains regarding the most appropriate regulatory limits to be enforced in the UAE, which should achieve a balance which simultaneously allows road safety targets to be realised, protects road and bridge infrastructure from unnecessary wear and damage, sustains local economies, and allows for strong growth. In this regard, Australia’s system of regulation and the recently conducted comparative assessment project can provide some guidance, and are discussed below.

3 THE AUSTRALIAN APPROACH TO HEAVY VEHICLE REGULATION

To date, most developed nations have relied on prescriptive rules and regulations to define limits on heavy vehicle weights and dimensions. While representing an effective tool in delivering safe heavy vehicle operation for some time, economic and environmental factors have necessitated the requirement for improved freight efficiency and utilisation of the available road network in developed nations. To address this requirement, Australian regulators have developed a ‘performance based’ approach to heavy vehicle regulation.

The notion of a performance (as opposed to a prescriptive) basis for the regulation of heavy vehicles was first introduced as part of the Canadian Heavy Vehicle Weights and Dimensions Study, conducted in 1986 (Ervin & Guy, 1986). Australia’s National Transport Commission (NTC), in co-operation with state road authorities and independent transport research consultants including ARRB, have further refined this concept, and delivered a regulatory package now known locally as the ‘Performance Based Standards’ (PBS) scheme. For this, Australia is widely regarded as one of the leaders in the development and implementation of schemes that regulate heavy vehicles. Similar performance based schemes are being developed and implemented in other nations including the European Union and Canada, with the Australian scheme in particular being adopted by South African regulators.

PBS offers the potential for heavy vehicle operators to achieve higher productivity and safety through innovative vehicle design, gains which are typically not available under a conventional prescriptive regulatory framework. PBS achieves this via an individual study of the on-road performance and behaviour of the vehicle and its load configurations. While performance studies can be conducted via computer simulation or physical field testing, the former is usually preferred due to the reduced cost offered by simulation.

Operating permits and road network access arrangements are provided based on the level of performance achieved by the vehicle in sixteen safety-related, and four infrastructure-related standards, which focus on quantifying vehicle performance in the following areas:

- engine and driveline performance – startability, gradeability and acceleration capability
- high-speed tracking on a rough road
- low speed off-tracking (vehicle and trailer swept path)
- static rollover threshold
- high speed steering input amplification and subsequent sway damping
- high speed lateral off-tracking
- stability under braking
- vertical and horizontal tyre forces, and tyre contact pressure distribution
- bridge loading.

Each of these areas is designed to target a critical area of heavy vehicle performance, such as the trailer sway behaviour, static rollover threshold and high-speed off-tracking discussed earlier. In addition to these measures, the standards also assess low-speed off-tracking, which identifies the envelope of road area required for a vehicle to complete a standard ninety-degree turning manoeuvre; an important consideration for multi-unit vehicle combinations operating in urbanised areas.

The sway damping measure investigates how effectively the vehicle combination ‘damps’ or reduces lateral sway oscillations following a steering input made by the driver. The standards which quantify performance related to infrastructure focus on tyre forces, and principally rely on prescriptive measures due to a lack of research in this area, while the bridge loading requirement uses a formula which relates axle-group spacing and axle mass to ensure that bridges and other structures will not be at risk of being damaged by the vehicle.

The method of assessment, performance measurement and required target of each of these areas are specified in the NTC’s performance based standards vehicle assessment rules (NTC, 2008). Visual depictions of high-speed transient off-tracking, and low-speed off-tracking provided by the Rules are shown in Figure 3.

Figure 3: High-speed transient off-tracking (left) and low speed off-tracking (right) performance measures (Source: NTC, 2008)

Within the PBS scheme, ARRB’s role as a vehicle assessor is to conduct individual studies of vehicle performance, which are predominantly completed via computer simulation. ARRB utilises AutoSIM, a custom-code computer simulation package which uses defined mathematical and physical relationships to model complex multi-body dynamic scenarios. ARRB’s version of the code permits the definition of systems at a mathematical level, which allows ARRB to include levels of detail in modelling which are not available through other
software packages, which typically only provide a basic ‘library’ of vehicle types. ARRB’s vehicle simulations and modelling techniques have been validated in numerous field tests and comparative studies conducted over the last twelve years.

The level of detail that this allows is crucial in accurately modelling heavy vehicles, some of which differ substantially in their configuration, connections and steering systems. Notwithstanding this, the influence of parameters such as suspension stiffness and tyre characteristics, fluid movement and centre of gravity height has been shown to be critical and can have vast effects on the overall level of performance achieved by a vehicle, so the modelling system must be capable of capturing the influence of these characteristics.

A performance-based approach has allowed Australian regulators to determine access arrangements for vehicles typically longer and heavier than those allowed under prescriptive regulations, as these vehicles in most instances have been designed to achieve a higher level of on-road safety than the typical vehicles defined under the prescriptive-based scheme. In many cases, permits have been granted for vehicles to operate at axle loads that are higher than prescriptive limits, which provides benefits for the local industry and economy, and permits greater efficiency for Australia’s freight task. As the scheme is in its relative infancy and only a small number of innovative vehicles have been granted access, a formal assessment or evaluation in terms of the scheme’s success at delivering road safety benefits and economic gains has not yet been conducted.

4 COMPARATIVE VEHICLE ASSESSMENT PROJECT

The capability to accurately model the dynamic on-road performance of heavy vehicles provides other opportunities separate to assessing compliance with a regulatory framework. This has been demonstrated in a project recently conducted by ARRB for the Joint OECD/ITF Transport Research Centre (JTRC) research working group into the safety, environmental and productivity impacts of current and future heavy vehicle operations, in the context of seeking to increase road freight volumes.

ARRB’s role in the project was to utilise vehicle modeling and simulation capabilities, within the context of the PBS regulatory framework and to conduct an investigation to benchmark the safety performance of representative freight vehicles from selected OECD member countries. Specifically, the investigation aimed to examine the safety impacts of baseline changes in the configuration of heavy vehicles, which included number of axles, overall mass and dimensions, and number and type of articulation points. In order to ensure that the effects of other characteristics such as tyres and suspension did not influence the results, typical generic figures were used for all vehicles assessed.

The OECD member countries were invited to submit representative vehicles for evaluation and to provide technical data for each. Vehicles were classified in three general categories: a ‘workhorse’ vehicle, a ‘higher capacity’ vehicle, and a ‘very high capacity’ vehicle. Workhorse vehicles were defined as the vehicle most commonly used within the member country for long haul transport. This vehicle is generally at the upper end of the weight and dimension range that is permitted access to the majority of the road network. Workhorse vehicles were defined in the study as having a gross mass of less than 50 tonnes and a length of less than 22 metres. Of the 40 vehicles in the study, 22 were classified as workhorse vehicles.

Higher capacity vehicles were defined as the vehicle typically operated under restricted access conditions, dependent on the suitability of the road network. This vehicle is usually
heavier and/or longer than the workhorse vehicle, having a gross mass of up to 70 tonnes and a maximum length of 30 metres. In the study, 13 vehicles were classified as higher capacity vehicles. Very high capacity vehicles were defined as vehicles typically operating under permit conditions and often in rural or remote areas, and typically heavier and/or longer than the higher capacity vehicle, having a gross mass of more than 52 tonnes and a length of more than 30 metres. In the study, 5 vehicles were classified as very high capacity vehicles.

A key observation of the study was the distribution of static rollover threshold (SRT) performance within the studied fleet. These results are outlined in Figure 4, separated by vehicle category. Australia’s PBS minimum performance requirement of 0.35 g is highlighted by a red line. SRT results were found to range from 0.28 g through to 0.43 g. Overall a total of 29 of the 40 vehicles assessed met the PBS performance requirement.

The results demonstrate a slight trend in increasing SRT result (better performance) with increasing vehicle payload capacity. All 5 of the very high capacity vehicles, 10 of the 13 high capacity vehicles and 14 of the 22 workhorse vehicles passed the SRT performance measure. This demonstrates that high-capacity vehicles can be designed to satisfy on-road safety requirements, and simultaneously deliver productivity gains.

However, it should be noted that overloading a vehicle to achieve a higher payload (as opposed to using a higher capacity vehicle) can dramatically decrease the static rollover threshold of the vehicle. For example, a 6 axle semi-trailer used in the study gave an SRT of 0.37 g, safely above the PBS requirement. However, if each of the axle groups were overloaded by only 15%, a situation which was noted by El-Qutob and Sharif (2003) to be prevalent, the vehicle would no longer be considered safe to drive on Australian roads due to the reduction in roll stability.

Another key finding of the study highlighted differences in performance brought about by varying vehicle configurations and connection types between adjacent vehicle units. The studied vehicles either had non roll-coupled connections between adjacent units (commonly
referred to as ‘drawbar’ connections, roll-coupled connections between adjacent units (fifth-wheel connections), or a combination of both. These different connection types are outlined in Figure 5.

![Figure 5: Non roll-coupled trailer units (top) and roll coupled trailer units (below).](image)

Generally, vehicles with non roll-coupled units performed well in low speed turning manoeuvres, however, these vehicles performed poorly in high speed dynamic manoeuvres in comparison to vehicles with roll-coupled units. This was reasoned to be due primarily to the extra articulation point that a non-roll coupling connection contains, which permits better trailer tracking at low speeds. However, the roll-coupling effectively shares dynamic roll forces between adjacent units, thereby reducing the overall influence of dynamic roll forces and effects on vehicle behaviour.

Overall, the results indicated that different geographic regions tended to focus on performance criteria which was highly dependant on their individual transport requirements. Vehicle performance was demonstrated to clearly reflect the needs of the freight task for the region in which the vehicles were designed to operate. As an example, European vehicles tended to focus upon improving low speed turning performance (lowering swept path) while the Australian, South African and North American vehicles tended to demonstrate improved high-speed dynamic performance. The results also clearly demonstrated that in some instances high-capacity vehicles can achieve similar or equal levels of on-road safety as typical workhorse vehicles. The investigation demonstrated that simulation of these representative vehicles was an effective tool for understanding and improving vehicle performance, safety and efficiency, highlighted areas where improvement may be needed and identified examples of good practice.

5 CONCLUSION

Road safety authorities and regulators in the UAE have many options available to them to encourage future heavy vehicle road safety efforts. The practice of overloading heavy vehicles has critical implications for road safety, and the recent work completed by Abu Dhabi and Dubai road safety authorities with regards to monitoring and enforcing axle load limits and vehicle dimensions should be applauded, as this is considered to be a critical area.

It is important that UAE-appropriate limits of heavy vehicle weights and dimensions be comprehensively understood. An investigation similar to the comparative assessment project recently conducted by ARRB is proposed as an effective means of determining suitable weight and dimensions limits for the UAE, as the investigation can be based on the current
UAE fleet, and can place focus on the critical safety measures for this region. This is a key outcome considering that vehicle performance has been demonstrated to be region and task specific, and consistency with this trend is considered to be beneficial for safety and efficiency. Overall, this approach is expected to be beneficial in delivering prescriptive limits which are appropriate to the UAE for heavy vehicles in the short term.

In the future, a regulatory system such as the Australian performance based standards scheme could be established within the UAE, and this would permit more productive vehicles to access the road network in a sustainable fashion. Such an approach would ensure that beneficial road safety outcomes are simultaneously delivered, thus improving the UAE’s road safety record. The scheme could be based on similar requirements and performance limits to the present Australian scheme, or utilise the findings from a comparative vehicle assessment program to determine the most appropriate requirements and limits.

The successful implementation of the scheme will require acceptance by each of the Emirates, a suitable regulatory framework, accredited vehicle assessors and auditors, and the continued enforcement of axle load limits and other vehicle characteristics. It is hoped that the UAE may learn a lot about the implementation of a new heavy vehicle regulatory scheme from the Australian authorities, as the details of how to implement such a scheme is beyond what can be described here.

REFERENCES


ABSTRACT
In transport the need for an effective fatigue management system has grown to give answer to the growing economic pressure and flexible working circumstances in the sector. Fatigue or sleepiness due to stress, health problems or harsh working schedules has lead to traffic accidents in the past. Recent research has shown that approximately 10 – 25 % of all accidents in transport companies have been related tot fatigue. Also fatigue can affect the health and wellbeig of drivers. Fatigue management systems can be seen as a set of measures, incorporated in the processes of the company, to prevent the existence of fatigue. A good fatigue management system identifies what exactly the fatigue risks in a company are, and what can the organization do to manage the risk of fatigue. This is preferably done by way of integrating fatigue management into the company’s safety management systems and general policies and procedures. Actually, an important aspect of preventing fatigue is that fatigue should be seen as just one of the risks (financial, safety, business continuity) in an organization.

In this research we have carried out 6 approachable fatigue management practices in road transport companies in the Netherlands. These practices were build upon the theoretical viewpoints of what a good fatigue management system should look like, for example: the need to look at the chain of events further away, a shared responsibility of management, schedulers and drivers together, assessment of early warning signals and integration within the organization's policy (safety mgt). But also, the practices had to be workable and useful in a variety of companies. The practices as well as some basic themes have been described and are compiled in a toolkit. This toolkit will be made available to all transport companies in the Netherlands via the internet.
1. Introduction and background

In recent years researchers and policy makers have increased attention towards the risks of fatigue in road traffic. Fatigue is thought to be an important hazard in road traffic though the magnitude of the problem is notoriously hard to measure. A new approach in road transport is the development of the concept of Fatigue (Risk) Management which aims to manage the occurrence of fatigue and its risks at a company level. This paper reports on approachable fatigue management practices which were introduced into Dutch a sample of road transport companies. In the oil & gas industry, offshore and in aviation, fatigue management systems are advised or obliged to companies in order to take measures to manage the fatigue risk and so improve their safety level. In road transport the development of the concept of fatigue management is quite new. Therefore, the Dutch ministry of transport is interested to learn from fatigue management measures in other sectors.

Fatigue has a considerable impact on road safety though the exact magnitude of the problem is notoriously hard to measure. Scientific estimates range roughly from 10-25% of accidents when evaluating accident characteristics after a crash event (e.g. Horne & Reyner, 1995, 2001; Flatley, Reyner, & Horne, 2004). But this shows a strong variation by road type (3-30% in Flatley et al.’s 2004 study). Additionally in surveys up to 50% of individuals report having ‘fallen asleep behind the wheel’ (see e.g. ETSC, 2001 and Jettinghof, Houtman & Evers, 2003).

Fatigue can be caused both directly and indirectly. A wide variety of factors can contribute to its occurrence, for example: unfavorable scheduling and rostering, working at night, traveling to and from work, physical fitness, medical conditions (OSAS), substance use or abuse and the quality of sleeping accommodations. Of these the design of the shift/work system is critical; it should allow sufficient opportunities for sleep and rest. Relevant aspects include for example: the length of shifts; night work; and, start and end-times. More information on these aspects is available in many publications, overviews are given for example in Folkard and Lombardi (2006) and Spencer Robertson and Folkard (2006).

Whilst it is clear that work hours are very relevant for fatigue they are by no means the only relevant factor. Even with relatively ‘mild’ work hours fatigue can occur when sleep or rest is reduced in quantity or quality by other factors, for example: second jobs, young children, social or psychological problems, stress, inappropriate use of medications. Sleep and rest is then impacted upon by factors outside scheduling or the work environment, see also Dawson and McCullough (2004) or Van Schagen et al (2003). In addition there are some examples where fatigue appears to be limited despite long work hours because of the demands and work content.

Fatigue management approaches try to take account of the complex causes of fatigue. In addition fatigue management should be ‘risk-based’ and take account of the possible consequences of fatigue.
The road transport sector

Fatigue is exceptionally important for the professional road transport industry. Heavy goods vehicle drivers tend to work relatively long and often irregular hours (e.g. Jettinghof et al, 2003; ETSC, 2001). There is also a long tradition of regulating hours of driving using community wide legislation (legislation 561/2006/EG). In addition, accidents involving heavy goods vehicles can have severe consequences for road safety due to the higher vehicle mass. Moreover, transport companies on the road have been faced with fatigue issues more and more due to new societal challenges. Working conditions in the transport sector are more and more characterized by economic pressure and flexible working circumstances. These are all characteristics of a demanding society (SCP, 2004) in which a battle is going on between safety values on the one hand and economy driven efficiency values on the other hand. Harsh working schedules and growing stress levels have lead to fatigue or sleepiness. Also fatigue can affect the health and wellbeing of drivers. Still, our busy lives and the competitive markets of transport make it hard to change our behaviour.

Fatigue is one of the factors that cause a lack of concentration to fulfill the driving task. For a good understanding of fatigue, the distinction is made between 'acute fatigue' and cumulative /chronic fatigue'. In the case of acute fatigue, the driver falls asleep at the wheel, a situation we do not want. At this point it is actually too late and a very risky traffic situation could not be prevented. In the case of chronic fatigue, acute fatigue can be a consequence. But, acute fatigue can also exist without chronic fatigue. A combination of factors, e.g. a long trip in warm weather conditions, etcetera can lead to acute fatigue. The chance this happens will increase when somebody is already chronically tired (Jettinghof et al, 2005).

What are the main factors that cause fatigue (Jettinghoff et al, 2003) have identified causes for chronic fatigue as well as acute fatigue using questionnaires. According to Jettinghof et al the main causes of chronic fatigue for freight transport drivers are: lack of skill discretion in work, the fact that work, and particularly working times, have a big influence on private life, having children, and the fact that private life has a big influence on work, an unhealthy life style (smoking, not eating enough vegetables, not taking enough time for a meal), health problems, use of medicine and sleeping problems. The main causes for acute fatigue are: driving alone, not being permanently employed, more infringements of the driving time rules and legislation, drinking more alcohol, having more meetings at work, being more often occupied with other things, a (too?) good cabin climate and health problems.

Diverse initiatives have been undertaken to improve the management of fatigue and risk by road transport companies. Throughout Europe, and abroad, a wide range of promising measures have been implemented. In Jettinghof et al (2005) an overview has been given of international measures to mitigate fatigue in the transport sector. Examples are: campaigns in Australia, Great Britain and France; in Australia and Sweden infrastructural measures like rumble strips, and in the US detection (warning) devices are still in development. Also, for example in Germany, the US and Canada, ‘fatigue management’- and ‘safety culture’ - programs have been developed. The campaigns are mostly focused on private drivers; for professional drivers, the fatigue management programs appear to be most promising for preventing fatigue and so enhancing road safety. Fatigue management systems, also called Fatigue Management Tool, Fatigue Risk Management Systems, or Fatigue Management Programs, have been implemented earlier in other transport modalities like aviation and rail and are seen as promising measures for reducing fatigue (Starren, 2008).
Fatigue (Risk) Management measures in the transport sector

Fatigue management systems, also called Fatigue Management Tool, Fatigue Risk Management System, or Fatigue Management Programs, have been implemented earlier in other transport modalities like aviation and rail and are seen as promising measures for reducing fatigue. The variation of programs and systems, and the diverse elements seen in fatigue management systems (e.g. training on awareness, procedures, incident registration, scheduling activities) brings us to the question of what actually defines a fatigue management system.

Fatigue management systems can be seen as a set of measures, incorporated in the processes of the company, to prevent the existence of fatigue. According to Dawson (cited in Starren et al., 2008) “Fatigue (Risk) Management Systems, tools or programs are comparable in that the main shift is away from compliance with a prescriptive set of rules toward an integrated hazard management system. A good fatigue management system identifies what exactly the fatigue risks in a company are, and what can the organization do to manage the risk of fatigue. This is preferably done by way of integrating fatigue management into the company’s safety management systems and general policies and procedures.”

In the study of Starren et al. (2008) an overview has been given of 36 fatigue management programs in the maritime, trucking and aviation industry, of which the 80 most frequently mentioned measures have been sorted. The measures were divided in reactive measures (measures specifically aimed at reacting to fatigue as it arises) and those that are aimed at preventing fatigue in a proactive way (long term prevention of fatigue). The proactive measures that are advocated to prevent fatigue, were divided into those regarding a) sleep and rest, b) scheduling, c) work characteristics/the workplace, d) health and e) other measures.

In the same study a distinction is made between the ‘old’ and ‘new’ approaches to fatigue and fatigue management. The old approaches used to be aimed at the direct cause of fatigue, e.g. a person who is already fatigued. Well known measures against fatigue were used, such as drinking caffeine, taking a nap and maybe a training on awareness and countermeasures (caffeine, goodtime sleep, hygiene, sleep disorders). This is now seen as too narrow an approach, which is too much focused on the employee and on the direct causes of fatigue. New insights lead to the need to look at the chain of events further away in time and location from when one is actually fatigued.

The main aspects of ‘old’ approaches are:
- Aimed at the direct cause of fatigue, e.g. a person who is already fatigued.
- Individual responsibility.
- Well known measures against fatigue were used (drinking caffeine, napping, training on awareness).
- Restrictions in the amount of working hours.
- Reactive.

The main aspects of the ‘new’ approaches are: need to look at the chain of events further away in time and location from the actual event.
- Initiated from within the organization’s policy (safety management).
- Shared responsibility.
- Counter-measures are defined at several levels, aimed at schedulers, operators (e.g. drivers) and executives/managers.

1 This doesn’t necessarily say anything about the quality of these measures.
• How to assess personal fatigue risks (early warning signals).
• Proactive.

The emergence of ‘new’ fatigue management systems has been based on the idea that fatigue should be prevented before someone gets tired. Next to the direct causes of fatigue there are indirect causes in the organization that can prevent fatigue before a situation occurs in which fatigue may lead to unsafe situations. Now new involved parties come in place as management and dispatchers. Not only the driver’s action, but also organizational policy decisions, the design of working procedures and various aspects of regulation can influence the level of fatigue.

Dawson and McCullouch (2005) conceptualize five distinct levels on which fatigue (risk) management should be focused: level 1, sleep opportunity offered in part by schedules; level 2, the actual sleep obtained; level 3, fatigue related behaviours; level 4, fatigue related errors; and, level 5, fatigue related incidents. We have used this model to guide our development of fatigue management measures in road transport. This model and its levels provide a framework for the multiple measure approach and can be seen as a reflection of the new approach of fatigue management systems. The model provides an overview of measures to prevent fatigues before fatigue actually occurs.

• Level 1 (long term, proactive) consist of tools for rostering and planning of (overtime) works.
• Level 2 (long term, proactive) consists of tools to identify insufficient sleep, for example sleep loss caused by a sick child during the night, or by attending a party on the weekend.
• Level 3 (long term, proactive) activities are aimed at (self-) reporting fatigue, e.g.: while talking to some the employees in the workplace during a coffee break you observe that one of the staff on your shift is exhibiting symptoms consistent with fatigue. You are aware that this individual has been pushing it pretty hard lately. What do you do?
• Level 4 (short term, reactive and proactive) activities reduce risk through “fatigue proofing” countermeasures, e.g. when somebody has had sufficient sleep, but nevertheless has considerable difficulty in staying awake and because you are concerned that there may be a risk of a fatigue-related accident or injury while driving to or from work, you call a cab.
• Level 5 (short term, reactive and proactive) consists of incident reporting and analyzing, e.g.: when an incident report is filed, and the investigation indicates that the employee had reported insufficient sleep prior to the incident

According to this model, there should be measures at several levels to prevent fatigue in order to be effective.

The main goal of this project has been to implement approachable fatigue management practices in transport sector. In this paper we will provide present 3 examples of fatigue management measures in road transport in practice. These measures were derived from state-of-the-art scientific knowledge wherever available and on experiences with fatigue management programs in different sectors. In addition care has been taken to adapt the measures as far as possible to the road transport setting. Road transport companies are often relatively small and communication between drivers and the company is often limited. Finally we will discuss relevant factors for an effective implementation of fatigue management in road transport.
2. Methods

The goal of the project was to design approachable and effective measures for preventing and managing fatigue amongst Dutch drivers of heavy goods vehicles. The approach chosen was one of close cooperation with stakeholders and companies. Evaluation of measures was limited to a qualitative assessment only. The following steps were taken in the project.

1. Development of a framework and a basic list of potential measures.
2. Discussion and selection within this list by a group of stakeholders and experts.
3. Implementation of some of these measures within 6 transport companies.
4. Case descriptions off other activities and measures within these companies.
5. Writing a toolkit with details on potential measures.
6. Short qualitative evaluation.

First a literature study was conducted. In this explorative study potentially effective elements of a fatigue management system were collected and described. In addition information was gathered on the conditions which appeared to be relevant for successful implementation of these measures.

The literature study served as a framework for the design of approachable and effective fatigue management measures in transport companies. The emphasis was on experiences with fatigue management in the transport sector, but information on the prevention of fatigue in other industries was also used. The literature study was focused not only on road transport drivers but more broadly on transport in general.

Subsequently the framework was presented in an expert meeting to representatives from stakeholders in the Dutch transport sector (transport companies, ministry of transport, inspectorate, insurance companies and sector organizations, and research). The participants of the meeting were each asked to prioritize the possible measures. Participant prioritized the methods based on their apparent effectiveness, approachability and ‘fit’ in the sector. Also conditions relevant for successful implementation were discussed.

This approach was chosen because it was considered important to find realistic measures which could potentially be used even in the very competitive world of road transport. The representatives had a good understanding of fatigue and excellent insight into sector specific challenges. However it is clear that expectations voiced by this group do not necessarily mirror the actual effectiveness of measures.

Next we recruited 6 transport companies to conduct pilot studies with in the project. The companies varied in their size and core activities. The companies were a convenience sample with sector organizations and the ministry working to recruit them. It was more difficult to involve smaller companies in the project because of the (limited) time investment needed. It is probable that there is some selection bias in this sample; companies participating probably have an above average motivation to take initiative on fatigue and other safety issues.

Company specific issues with fatigue and safety were explored in a first interview. On the basis of this interview a limited number of fatigue management measures was selected for implementation in the company. The measures were selected based on:
- theoretical viewpoints of what a good fatigue management system should look like, for example: the need to look at the chain of events further away, a shared responsibility of
management, schedulers and drivers together, assessment of early warning signals and integration within the organization’s policy (safety mgt).
- useful in the perception of the company
- workable in the setting of the company.
- compatible with the culture and working methods within the company and, if existing, the current safety management procedures.
- focused on the specific (fatigue) risks in the company

The company of course needed to agree on the measures to implement. Once the company representative agreed, the measure was implemented together with the company.

We found while visiting the companies that many activities were already being undertaken to reduce fatigue related risks both formally and informally. Therefore in some of the companies few new measures were taken but descriptions of existing measures were made. All descriptions have been organized around some basic themes and were compiled into a toolkit. This toolkit will be put on the internet as and made available to all transport companies in the Netherlands.

Lastly a short qualitative evaluation was conducted with all individual transport companies. The evaluation was conducted by telephone interview. The evaluation of measures was limited in this project. This is a known limitation of the research design. Future research could include more formal measurement of the effectiveness of fatigue management measures in the transport sector.

3. Results: effective fatigue management measures and 3 examples of the case descriptions

The different elements of an effective fatigue management system, as described in section 1, provide a set of actual fatigue management measures and preconditions to consider when implementing fatigue management for transport companies on the road. After consultation of experts and practitioners in the sector, a selection has been made for themes for of interventions:

1. Fatigue Awareness
   - workshops focused on collective understanding and agreement;
   - social dialogue based on the results of a fatigue survey;
2. Working conditions
   - implementation of fatigue procedures related to the working conditions;
   - flexible rostering;
3. The driver’s health
   prevention of stress and workload;
   - stimulation of a healthy lifestyle;
   - rules of thumb at the beginning of the work shift.
4. Dealing with fatigue at the road.
   - rules of thumb: what to do.
   - rules of thumb: recognizing of fatigue;
5. Learning from incidents and accidents in the past
   - tips for analyzing accidents (based on Horne & Reyner, 1995).
6. Assurance of fatigue management /fatigue management policies.
Driver coordinators
- “Barers” of Culture as facilitators for the issue of fatigue.

Examples of case studies.

Six approachable practices of fatigue management have been co-created together different transport companies. The practices have been designed and implemented based on the theoretical viewpoints of what a good fatigue management system should look like and. But also, the practices had to be workable and useful in a variety of companies. The cases have been developed in interaction with the companies and evaluated afterwards. The best practices have been described and specific measures will be provided as a toolkit for transport companies in the Netherlands to prevent unsafety on the road due to fatigue.

As an illustration we will present three of the cases in which the implementation of one or more measures is described.

Case 1: Prevention of workload and stress at Company A.
For company A, national carrier in food products in food retail and food service (750 employees), a professional image is important. One of the ways they do this is to give attention to the well-being of their drivers. They have strict rules in the amount of working hours. As the company transports fresh food and frozen food which has to be in supermarkets on time, their customers require on-time deliverance. These high demands can give pressure to truck drivers. On the long term this can cause stress, workload and fatigue. This is something company A wants to prevent.

Customers have high demands on on-time deliverance which cause high workload with all kind of consequences. An example is an on-time deliverance policy of one of their customers. This policy means that the company has an on-time deliverance of more than 97% during a workweek, the carrier receives an extra bonus. These kind of scheduling can give additional pressure on the driver, which can cause errors and damage. For that reason the company doesn’t agree with this bonus policy and communicates strongly that driving without suffering damage is appreciated more than driving on time. The company is in their policy aiming at prevention of damage and safe driving: “We see that when you don’t aim at fast deliverance, truck drivers will not only work more relaxed but also work faster and more efficient!”

“We don’t want to rush our drivers”. This means that schedulers don’t make unnecessary phone calls to their drivers. If a driver notices that he won’t manage it anymore to deliver his load on time, we accept him to communicate this to the planner in time. By doing this, the planner will have the possibility to inform the customer and to find solutions. As a driver it is not necessary to feel rushed: the problem should be at the planning. Only they can find solutions. Younger truck drivers with less experience easily experience more pressure. We communicate to them that they shouldn’t have that high demands of themselves and that it is logical that they perform less than drivers with more experience.

Another way to support drivers and give attention to their well-being is by setting up a system of “driver coordinators”. These coordinators are supervising the truck drivers during their daily work and assist them with practical problems. As the coordinator works closely with the truck drivers, they know which issues are important to them. The coordinator also works closely with planning and management. For this reason they have a good feeling for how to solve problems in the company. The coordinator communicates this to the management and
gives advice how to improve the policy. In this way the company is capable to cope with actual problems and take the right actions which fit with the needs of their drivers.

Company A finds it important that drivers take their own responsibility in taking daily rest on time. Each driver receives a training of 5 days. 2 days training are given by the driver coordinator. 3 days training are given by an experienced truck driver at the workplace. In the training a lot of attention is given to the values and standards. One of these values is the importance of maximal working hours (48 hours a week) and maintaining resting times during the day. They send a letter to their employees to inform them about the necessity of healthy working times and rest. In the letter the own responsibility of the driver is emphasized. If the daily rest time isn’t possible due to a narrow time schedule, the driver has the responsibility to contact immediately the planner. The planner has to find a suitable solution. “The planner has a problem and not the truck driver.

In making the time schedules we take the capacity of our truck drivers into account. Some drivers like variety in their work and love different rides while variety causes stress for some other drivers. Drivers who like structure are assigned the same rides where possible. By taking individual capacity into account, workload and stress can be prevented. We also communicate the time schedules a long time ahead to our drivers. This gives structure to drivers which enables them to make better planning of their private time (like doing sports). The work this company is doing (distribution for supermarkets and other shops) is easy to schedule in a structured way.

Some drivers arrive every day at their work in a hurry and just on time. They leave stressed. The company gives the following advice: “Put your alarm clock one hour earlier: before you start to work you can have a cup of coffee and a chat with your colleagues, this will give you a good and relaxed start!”

Case 2: Fatigue management by introducing a special night shift in Company B.
This case describes the special night shift to load trucks of a Dutch Transport Company, family-owned since 100 years. The company employs 60 employees; most of them are working part time. They transport and store a multitude of goods (pallet and colli). In 2008 the company decided to install a special night shift to take over loading tasks from truck drivers, early in the morning.

The idea behind this special night shift is to take away work stress from drivers and to give drivers a longer night rest. Due to this shift drivers are able to sleep longer, will not be disturbed in night rhythm and are therefore in the opportunity to start fit at the job. The special night shift also offers new job opportunities for employees who (through for example family of personal circumstances) need to work in a more steady time schedule or don’t want to travel a lot.

People on duty in the companies’ special night shift are (ex-) truck drivers. The night shift consists of 5 employees. For working in night shifts it is important to be aware of specific risks. Do’s and don’ts are for example: take care of sufficient darkness and silence when sleeping during the day; put on sunglasses in the morning after work, dare to be severe towards family for your sleeping hours; don’t mix family obligations too much with resting time during the day.

Evaluation of the special night shift shows:
1. for night shift employees
- More possibilities to combine personal and family circumstances with their job at the transport company;
- Overall more time to sleep and rest during the week, and have more time during the day;
- For some employees it is still hard to work at night. Especially above the age of 50 it is difficult to adapt to another biorhythm.

2. for the company:
- Loading trucks is now executed by experienced truck drivers, less damages are reported;
- Loading mistakes are now reported in an earlier stage and therefore easy to restore;
- It is interesting to offer more job opportunities to truck drivers.

3. for truck drivers:
- More energy during the day, because loading the truck is done by (experienced) colleagues;
- The job of truck driver becomes less stressful.

Case 3: Condensed workshop in weekend hours – company C

Company C runs a total of 7 vehicles and employs 8 to 9 mostly drivers most of whom work fulltime or more. The relatively small company size is typical of Dutch transport companies. Whilst there are definitely large scale operators active on the Dutch market a large fraction of the market is served by these small operators. Large and small scale companies alike both work under intense competitive pressure and often with razor thin margins. This is why our approach in this company needed to be as efficient as possible and realistic goals needed to be set.

After discussion with the company owner we arranged to organize a condensed workshop in weekend hours. All of the company’s drivers, their driver with planning responsibilities and the company’s owner and director were present. Three main goals were set for the workshop:
- To increase awareness of fatigue in the participants’ everyday practice
- To increase knowledge about the causes and consequences of fatigue amongst the drivers and planner
- To have employees and management create a set concrete company-specific measures for preventing fatigue-related risks within the company

To help increase personal awareness of fatigue we started the workshop with a quick self-test questionnaire. The very small questionnaire was derived from literature but slightly adapted and reduced. Our goal was not to objectively measure relative fatigue amongst participants but rather to confront participants with the applicability of the topic to themselves and their co-workers. Scores were quickly compared and used to ask drivers about personal experiences with fatigue on the road. In a subsequent presentation well known research on causes and effects of fatigue was presented to the drivers. In addition we gave an in-depth look at a real road transport accident on which we had extended information. This accident involved multiple fatalities, clearly apparent fatigue of a HGV driver, very long hours and strong managerial pressure put on the driver.

In the second half of the workshop participants were asked to answer individually three questions about fighting fatigue “what can I do?”, “what can we do together?” and “what can the company do”. Many useful suggestions were brought to bear by the participants.
and gathered together. The morning ended with a voting session in which everyone was given a number of votes to determine the best ideas which needed to be implemented in the future.

4. Conclusion

In this project the challenge was to use state-of-the-art knowledge to design approachable and potentially effective, and workable fatigue management practices in transport companies. According to the Dutch Ministry of Transport this is helpful to trigger the companies to tackle fatigue effectively without too much costs in time and budget. The several illustrative cases show us some good examples.

Of course there were also barriers. The implementations and evaluation of the practices has led to the following statements to conclude:

- Fatigue management approaches are difficult to realize in small companies. Very little time is felt to be available due to strong competitive pressures. For example: the typical small companies are not interested in formal management systems but are best helped with practical interventions.
- In all types of companies. A lot can be done in a short workshop setting. Knowledge can be shared and good specific solutions can be thought up.
- Using a quick questionnaire can help give drivers insight into their own fatigue.
- By initiating ideas in several organisational levels, a shared responsibility between management and drivers was promoted.
- Small creative/innovative changes in the working process can lead to a considerate improvement in fatigue related behaviour.
- Openness of culture, social dialogue and communication on the workfloor is crucial to mitigate fatigue effects, especially in the transport sector there are approachable improvements to make.

The fatigue management practices have been evaluated positive by the companies, with still a minimum amount of effort. This way companies were prepared to take the measures, even in these times of financial crisis. At the moment the time is too short - after the implementation – to measure the actual effects on (traffic) safety. Moreover, due to time and budget constraints, it was only possible to implement single measures in the companies. For lasting success, it is important to foster the systemic character of FMS, for example the integration of fatigue management measures in all company levels and the focus on shared responsibility. For research in the future we advise to monitor fatigue related accidents in the future. In this way we will receive a better insight in the prevalence of fatigue and so the effectiveness of measures.

REFERENCES


Contents session 18  Health issues and raising awareness

In which Way an NGO Could Help to Improve Traffic Safety in a Developing Country?
Alberto José Silveira, Luchemos por la Vida, asociación civil, Argentina

Research Directions for Guidelines in Road Safety Engineering
Peter Croft, ARRB Group, Australia

Following the Lives of Accident Victims and their Families
Joanna Zakowska, Gdansk University of Technology, Poland

Road Safety in Tanzania – A Questionnaire Study
Katja Kircher, VTI, Sweden

Assessment of Road User Behavioural Aspects of Relevance to Traffic Safety in UAE
Nada Al Naser, Roadway Transportation and Traffic Safety Research Center (RTTSRC)/United Arab Emirates University (UAE University)
In which way an NGO could help to improve traffic safety in a developing country?

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ABSTRACT

Traffic safety is a matter and a primary responsibility of the Government (besides being the responsibility of each individual citizen). When the Government does not fulfill that responsibility, many citizens feel powerless and, at the same time, want to contribute solutions to put order in traffic, to help increase traffic safety and decrease the number of fatalities and injuries. But they do not trust to be able to make important contributions because, in general, everybody thinks that traffic safety is, basically, a Government job.

The purpose of this presentation is to share the contributions for the increase of traffic safety made by an NGO working for almost 20 years in a developing country, Argentina, in which, like in most of these cases, authorities do very little about this subject. Our purpose is to encourage and motivate all individuals and the NGOs interested in traffic safety to renew their efforts to reach significant goals in traffic safety with the experience of Luchemos por la vida as a starting point.

Starting from zero, with very little resources and the help of a few enthusiastic volunteers, we developed a multiple-approach plan aimed at the individual “in the community” to generate a social change of attitudes towards traffic accidents and behavior on the streets, and a better awareness about traffic as a system in order to provoke changes in the system of individual beliefs and attitudes. To do this, we decided to influence public opinion with a view to generating spaces of reflection and self-examination, and of social debate regarding the problem of accidents and its relationship with individual and social behaviors of all citizens, in general, and authorities, in particular. With this in view, we decided to privilege work among: mass media, government and traffic safety education. Some of our accomplishments are:

- Creating and maintaining a permanent traffic safety teaching and awareness campaign on the main TV and radio media of our country for over 18 years, to this day.
- Promoting laws for greater traffic safety.
- Demanding their effective enforcement by means of effective controls and punishment.
- Promoting the inclusion of crimes against traffic safety in the Crime Code.
- Producing educational materials such as the educational video “Keys to Safe Driving”, specially produced to help create awareness and educate drivers, mainly those who are requesting or renewing their driving licenses. This video is available in Spanish or English (dubbed) for free to all driving license granting centers.
- Luchemos por la Vida magazine.
- A wide web page in Spanish and English with lots of information and opportunities for involvement.
- Ongoing communication and interaction with the media.
- The annual Luchemos por la Vida Awards.
A National Traffic Safety Education Plan called “Schools for Life,” aimed at students of elementary and high schools.

One of the most important results of these actions was to have made traffic safety a concern for all of society and, especially, for politicians, who have been forced to include it in their agendas.

In which way an NGO could help to improve traffic safety in a developing country?
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Introduction

In this presentation I would like to share the experiences and approaches of a non-governmental, non-profit organization called Luchemos por la Vida (“Let's fight for life”) that works to prevent traffic accidents in Argentina, a developing country with 39 million inhabitants, where 22 people are killed each day (more than 8,000 a year)*, another 130,000 are injured each year, and dramatic material losses (estimated in U$S 10 billion a year)** occur in traffic collisions. These figures turn out to be unfortunately high for the population of the country where there are 7,738,000 circulating vehicles (ADEFA, 2007).

These figures are also too high when compared to those of developed countries, which have a fatality rate six to ten times lower (considering the number of circulating vehicles). In 2008, 1,066 people died in Argentina for each 1,000,000 circulating vehicles.

TRAFFIC ACCIDENTS IN ARGENTINA
PROVISIONAL NUMBER OF DEATHS IN 2008: 8,205
(Daily Average: 22  Monthly Average: 683)
Figure 1
Source: Luchemos por la Vida
### TRAFFIC ACCIDENT FATALITIES IN THE WORLD

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Fatalities per million inhabitants</th>
<th>Fatalities per million cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Norway</td>
<td>61</td>
<td>76</td>
</tr>
<tr>
<td>2008</td>
<td>Sweden</td>
<td>46</td>
<td>92</td>
</tr>
<tr>
<td>2007</td>
<td>Germany</td>
<td>84</td>
<td>99</td>
</tr>
<tr>
<td>2006</td>
<td>Italy</td>
<td>86</td>
<td>107</td>
</tr>
<tr>
<td>2002</td>
<td>Finland</td>
<td>80</td>
<td>113</td>
</tr>
<tr>
<td>2001</td>
<td>Denmark</td>
<td>81</td>
<td>113</td>
</tr>
<tr>
<td>2005</td>
<td>Japan</td>
<td>83</td>
<td>118</td>
</tr>
<tr>
<td>2001</td>
<td>Switzerland</td>
<td>82</td>
<td>131</td>
</tr>
<tr>
<td>2001</td>
<td>Australia</td>
<td>90</td>
<td>139</td>
</tr>
<tr>
<td>2004</td>
<td>The Nederlands</td>
<td>59</td>
<td>147</td>
</tr>
<tr>
<td>2004</td>
<td>Spain</td>
<td>89</td>
<td>148</td>
</tr>
<tr>
<td>2004</td>
<td>France</td>
<td>79</td>
<td>154</td>
</tr>
<tr>
<td>2001</td>
<td>Canada</td>
<td>87</td>
<td>156</td>
</tr>
<tr>
<td>2002</td>
<td>Island</td>
<td>102</td>
<td>158</td>
</tr>
<tr>
<td>2004</td>
<td>Great Britain</td>
<td>63</td>
<td>160</td>
</tr>
<tr>
<td>2000</td>
<td>Irland</td>
<td>109</td>
<td>180</td>
</tr>
<tr>
<td>2003</td>
<td>United States</td>
<td>154</td>
<td>198</td>
</tr>
<tr>
<td>Year</td>
<td>Country</td>
<td>Fatalities</td>
<td>Injured</td>
</tr>
<tr>
<td>------</td>
<td>------------------</td>
<td>------------</td>
<td>---------</td>
</tr>
<tr>
<td>2001</td>
<td>Austria</td>
<td>118</td>
<td>217</td>
</tr>
<tr>
<td>2001</td>
<td>Luxembourg</td>
<td>158</td>
<td>220</td>
</tr>
<tr>
<td>2005</td>
<td>Belgium</td>
<td>143</td>
<td>249</td>
</tr>
<tr>
<td>1997</td>
<td>Israel</td>
<td>89</td>
<td>310</td>
</tr>
<tr>
<td>1998</td>
<td>Slovakia</td>
<td>85</td>
<td>321</td>
</tr>
<tr>
<td>2001</td>
<td>Portugal</td>
<td>146</td>
<td>341</td>
</tr>
<tr>
<td>2001</td>
<td>Hungary</td>
<td>123</td>
<td>370</td>
</tr>
<tr>
<td>2005</td>
<td>Poland</td>
<td>143</td>
<td>324</td>
</tr>
<tr>
<td>2001</td>
<td>Czech Republic</td>
<td>155</td>
<td>444</td>
</tr>
<tr>
<td>2001</td>
<td>Bulgaria</td>
<td>145</td>
<td>519</td>
</tr>
<tr>
<td>1998</td>
<td>Ukraine</td>
<td>110</td>
<td>570</td>
</tr>
<tr>
<td>2000</td>
<td>Turkey</td>
<td>84</td>
<td>584</td>
</tr>
<tr>
<td>1998</td>
<td>Korea</td>
<td>31</td>
<td>692</td>
</tr>
<tr>
<td>2006</td>
<td>Brasil</td>
<td>185</td>
<td>977</td>
</tr>
</tbody>
</table>

| 2008 | Argentina       | 211        | 1066    |
| 2000 | Algeria         | 117        | 1267    |
| 1998 | South Africa    | 228        | 1358    |
| 1998 | Nigeria         | 30         | 1380    |
| 2001 | Romania         | 122        | 1414    |
| 1998 | Egypt           | 84         | 1642    |
| 1998 | Tünez           | 143        | 1710    |
| 1998 | Jordan          | 139        | 1920    |
| 1997 | Morocco         | 106        | 2110    |
| 2001 | Peru            | 123        | 2883    |
| 2004 | China           | 200        | 28581   |

Table 1

The situation in Latin America is similar as to fatalities, though the reasons that lead to them may vary in some cases. As can be seen, the traffic safety situation is, in general, very poor:

Figures 3 - 4
Though with different angles in each country, the situation in Latin America shows, in general, some common characteristics:

* Traffic safety is not included in the politician’s agendas and is not an item of state policy. Usually, there are no leaders responsible for implementing traffic safety policies or a serious budget to implement them or enough political support for the subject.

* The lack of danger awareness causes people to think that they cannot suffer an accident, which leads them to believe that they do not need to follow certain safe conducts to avoid accidents (reducing speed, not drinking and driving, wearing a seat belt and/or a helmet, etc.), even when they are imposed by law.

* Enforcement is virtually inexistent and when there is some attempt to implement it, it is usually not effective, because it is not done properly and not long enough. Enforcement
agents are usually part of the widespread corruption which is practiced habitually by road users. Consequently, effective punishment actions are very rare, and this leads to a generalized feeling of impunity in traffic.

* Urban road planning is only occasional and partial. There is a lack of a comprehensive, orderly road planning and traffic safety is not a key element in such plans.
* Technical control of vehicles is, in reality, almost inexistent.

* There is no massive system of traffic safety education, adequately planned and carried out through the media.
* Systematic traffic safety education in elementary and high schools is practically unexistent and where existent, it is occasional and inadequate.
* Driving licenses, in general, are granted without proper preparation on the part of the driver (even worse in the case of professional drivers). There should be a thorough theoretical and practical exam with an emphasis on safe driving. In many cases, licenses are granted just because the driver is a friend of some official or after a bribe.
* Government officials are not, in many cases, a good example of compliance with safety rules; even worse, they tend to think that they are somehow authorized to break them.

Let's take a look at some numbers in Argentina

### VIOLATIONS AND RECORDS
#### IN THE CITY OF BUENOS AIRES

<table>
<thead>
<tr>
<th>Month of June, 2002</th>
<th>Violations in one day</th>
<th>Violations in one month</th>
<th>Records(*) taken in 1 month</th>
<th>Percentage according to number of violations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SERIOUS VIOLATIONS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PRIVATE VEHICLES)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossing with red light</td>
<td>1,903,560</td>
<td>57,106,000</td>
<td>9,639</td>
<td>0.0168 %</td>
</tr>
<tr>
<td>Not respecting pedestrian priority</td>
<td>701,040</td>
<td>21,031,000</td>
<td>39</td>
<td>0.000185 %</td>
</tr>
<tr>
<td>Not using seat belt</td>
<td>1,090,600</td>
<td>32,718,000</td>
<td>1,679</td>
<td>0.0051 %</td>
</tr>
<tr>
<td>Children on front seats</td>
<td>43,100</td>
<td>1,293,000</td>
<td>28</td>
<td>0.00216 %</td>
</tr>
<tr>
<td>Not using helmet (motorbikes/mopeds)</td>
<td>40,800</td>
<td>1,224,000</td>
<td>440</td>
<td>0.03594 %</td>
</tr>
<tr>
<td>Drink and drive</td>
<td>?</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No head restraint</td>
<td>?</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Racing on public streets</td>
<td>?</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passing another vehicle on the right</td>
<td>?</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **SERIOUS VIOLATIONS** |
| (Public transportation - buses) |
| Not coming close to the stop | 794,000 | 23,820,000 | 9 | 0.000037 % |
| Crossing with red light | 302,400 | 9,072,000 | 524 | 0.00577 % |

| All violations/records/percentages | 4,875,500 | 146,265,000 | 12,358 | 0.008442 % |

*Most violations recorded are never effectively punished, for different reasons the analysis of which would be too long to be included here.*

Table 2
Source: Luchemos por la Vida
These data, analyzed from another angle, means that for each
5,925 violations to red light, one record of violation is taken.
539,261 violations to pedestrian priority, one record of violation is taken.
19,486 violations to use of the seat belt, one record of violation is taken.
46,178 violations to the rule of "no kids on front seat", one record of violation is taken.
2,782 violations to the use of the helmet in motorbikes/mopeds, one record of violation is taken.
2,646,666 buses that do not get close to the bus stop, one record of violation is taken.
17,312 buses that cross with a red light, one record of violation is taken.

If we analyze the total estimated number of violations mentioned compared to the number of records taken, an average of one record is taken every 12,000 serious violations observed.

If the total number of violations of all kinds (not included in this research) would have identical ratio with records taken, we could establish that IN BUENOS AIRES, SOME 318 MILLION SERIOUS VIOLATIONS ARE COMMITTED EACH MONTH, OF WHICH ONLY 26,689 ARE RECORDED.

It is clear, then, that the enforcement authority -the Police in this case; in others, city officers-, do not carry out their duty as they should:

**SEAT BELT USAGE IN THE CITY OF BUENOS AIRES**
(August 19, 2008), performed by Luchemos por la Vida

Figure 7
Source: Luchemos por la Vida

-Total of vehicles observed in 2008: 5,451
-Times: Monday thru Friday, 8 am – 6 pm.
-Though no formal observations were made in night hours and on holidays, use rates are lower at those times.
Let us keep in mind that the city is the place where use rates are the highest; just on the other side of the divisory line to the adjacent locations, use rates drop to less than 20% and in the interior of the country, in average, less than 12%.

Let us keep in mind that the city is the place where use rates are the highest; just on the other side of the divisory line to the adjacent locations, use rates drop to less than 20% and in the interior of the country, in average, less than 12%.

**BICYCLES ON THE ROAD**

Research made in the city of Buenos Aires (May 2006) on a total of 970 bicycles observed.

<table>
<thead>
<tr>
<th>Violation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving against the traffic</td>
<td>36%</td>
</tr>
<tr>
<td>Not stopping at red light</td>
<td>77%</td>
</tr>
<tr>
<td>No lights</td>
<td>67%</td>
</tr>
<tr>
<td>No reflective material</td>
<td>38%</td>
</tr>
<tr>
<td>Not respecting pedestrian priority</td>
<td>86%</td>
</tr>
<tr>
<td>Not slowing down at corners</td>
<td>82%</td>
</tr>
<tr>
<td>Not hand signals when maneuvering</td>
<td>96%</td>
</tr>
<tr>
<td>Not wearing a protective helmet</td>
<td>93%</td>
</tr>
</tbody>
</table>

Table 3
Source: Luchemos por la Vida

**A 8% of the deceased were cyclists, according to our data.**

**Time for action**

In the midst of this sad reality, trying to follow the successful model of traffic safety from developed countries, in 1990, we created **Luchemos por la Vida, the first non profit organization** as a means to achieve a new reality in traffic safety in Argentina. It wasn’t easy. We didn’t receive any kind of financial support from government agencies or persons. So far, most of the working has been done with the cooperation of volunteers who came to help after work. On the other hand, where should we start and how should we go about this task in a country while the population at large participated every day, both suffering and inflicting wrongs, attributing each accident to fortuitous and chance actions, taking each tragedy as a personal misfortune, the result of destiny or fate?. Meanwhile, the public authorities, who were supposedly responsible for this problem, evaded it out of ignorance or by closing their eyes to reality, in order to avoid assuming responsibilities which they believe would not bring them any short-term political gain. However, many things have been accomplished.
One of our first efforts was to encourage the passing of a new traffic law. Finally, the government passed a decree (692/92), and in 1995 the new National Traffic Law (24,449), ruling on the use of seat belts, helmets for motorcycle and moped riders, the prohibition of taking children on front seats, maximum BAC levels, etc.. We are working so that it is properly enforced now.

Meanwhile, we decided to carry out a diagnosis on:

1) The level of technical knowledge of drivers in some topics related to traffic safety and accident prevention
2) The behavior of road users in the traffic system regarding the topics evaluated theoretically
3) The relationship between both results (in order to establish the grade of correspondence between knowledge and behaviors)

We gathered information by means of surveys carried out among drivers concerning on some key topics (traffic lights, seat belts, alcohol, speeding, circulation on bicycles, helmet use, causes of accidents, etc.), and this information was compared with systematic observations made in traffic of these topics.

The main conclusion was the lack of correspondence, but rather contradiction, between the acceptable level of results about theoretical “knowledge” and the development of risk behaviors in road users. This disagreement indicated a superficial use of information.

These conclusions had an enormous importance when planning strategies to increase traffic safety. We knew that to inform about traffic norms and safe conducts is a necessary but not a sufficient condition to achieve changes on behaviors in favor of traffic safety and accident prevention. We needed to “motivate” drivers to change their attitudes and to develop healthier habits. Even more when the enforcement doesn’t work at all.

A multiple-approach plan

So, we decided to develop a multiple-approach plan aimed at the individual “in the community” to generate a social change of attitude towards traffic accidents and behavior on the streets, and a better awareness about traffic “as a system” in order to provoke changes in the system of individual beliefs and attitudes. To do this, we decided to influence public opinion and to privilege work among: mass media, government and traffic safety education.

Mass Media

In this field we carried out the following activities:

1) Mass awareness campaigns, by means of advertising spots on radio and TV. Since 1992, this is the only campaign that has been on the air for more than thirteen years now, designed to prevent more road accidents, aiming continuously at awakening interest and concern, that is, awareness of the serious problem of traffic accidents in our country, in order to increase the “perception of risk” among road users and by providing concrete information on safe behaviors connected with the main factors causing accidents and mortality in traffic (speeding, drinking and driving, night driving, use of seat belts, helmets, etc.)

To estimate the broadcasting frequency of these campaigns, we can mention: -Our public campaign was ranked in the 11th position among the 100 companies with the highest
publicity investment during 1994 according to the business-magazine “Mercado” (January 1995), with an estimated cost of USS 20.287.000.-, only 2 points below Pepsi-Cola Company. Of course, we didn’t pay that money, it would have been impossible for our organization. Instead, we got a free airing time regulated by law, for non profit and community welfare the first years and last years we are receiving the voluntary donation of time from radio and TV companies.

2) **Work with the press.** We established a permanent communication channel with the graphic press (newspapers and magazines), radio and TV, sending information continuously pressing for:

- Divulging topics on traffic safety and accident prevention in news and special programs. For this, we send short news clips and participate in TV programs.

- Presenting information highlighting the causes of accidents that have been published, locally or internationally.

3) **Follow up of advertising and TV**, in particular:

- Control and request of changes in commercial publicity or presentations showing behaviors contrary to traffic safety with positive connotations. As an example, we asked Ericsson to change a graphic publicity that showed a beautiful couple riding a motorbike blissfully without helmets.

- Proposals to introduce comments or safe behaviors in fiction characters of programs produced by local TV.

4) **Public recognition of positive actions of people** who help promote traffic safety in every form, through the *Annual Luchemos por la Vida Awards*, which include professional drivers, teachers, journalists, professionals, companies, mass media, etc.

5) **Luchemos por la Vida magazine**, a quarterly publication for free designed to promote public interest on traffic safety and prevention.

6) **Information and participation on the Internet.** We opened a web site in 1998 in order to divulge information and news nationally and internationally. In this site we include some sections to participation of the community such as “Reports of dangerous situations in traffic”, “What happened to you is important” to share experiences of traffic accidents, “Reports of safety defects in cars”, “Reports about public authorities breaking the law”, a “Forum” and others.

**Government**

Perhaps the most difficult activity we are carrying on with, is to work with government authorities through:

- Presentation of proposals of laws and actions in the field of enforcement, organizing traffic, road planning and traffic education.
- Nowadays, promoting the inclusion of crimes against traffic safety in the Crime Code.
- Offering training courses and seminars for public officials on traffic and traffic education.
Because of the lack of official information about traffic accidents fatalities figures we began to gather data about them. As a result, we made the first national statistics available to the public to encourage the government to take action on this.

Systematic Traffic Education

- For SCHOOLS, through a National Traffic Safety Education Plan, called “Schools for Life,” aimed at students of elementary and high schools, through participatory workshops (reaching 90,000 students in our capital city and the province of Buenos Aires up to now).

- **Our most recent production is the DVD film: “Pedestrian Hunters”**. This new teaching material developed by our Association is offered at no cost to public and private elementary schools that request it. The film promotes student participation and stimulates their ability to reflect on the subject of traffic system and safe pedestrian behaviors.

- We organize training courses for teachers.

- For SAFE DRIVERS. We have been dictating courses for new drivers and for people who are renewing their driving license during the last seven years in the Traffic Administration of of Buenos Aires city. (This activity allowed over 400,000 people to participate in the awareness program).

- We elaborate educational materials such as the video “Keys to safe driving” made to educate drivers, specially those who are requesting or renewing their driving licenses. This material, available in spanish and english (dubbed) is provided free of charge to all driving license granting centers from any country that requests it.

- (We are also teaching courses on “safe driving” for drivers of companies, bus drivers, etc.)

Analyzing:

The possibilities of analyzing in detail the results we have achieved in these 19 years of work exceed the time we have available. The programs, each different in scope, realization and achievements, have contributed to generating an important change of attitude in the population at large regarding this problem.

As some examples of positive results we can mention:

- **The results of the mass-media campaigns** among public. It was measured by post-campaigns tests and systematic observations of traffic. Both results were positive. **with important improvements in traffic behavior in specific topics**, such as wearing seat belts in cars and helmets on motorcycles, some improvement in respecting the priority of pedestrians, etc.

- We believe that the approach from different fields, with a special emphasis on mass media, has enabled us to create **a new social awareness on this problem**. As an example, in polls previous to national and city elections, in 1999, the traffic and accident problem was included by people among the 10 most important problems to be solved by politicians, who have been forced to include it in their agendas.
As a result, the National Traffic Safety Agency has been created recently, and an agreement of mutual cooperation was signed with Luchemos por la Vida, which is currently advising the Agency in different requested issues.

- Small groups of people have also appeared in different parts of the country who demand greater traffic safety.

**We received international recognition of our activities, for example, from:**

- A report about Traffic Safety in Latinamerica of *The Interamerican Developing Bank (1999)* carried out by The Danish Road Directorate, mentioned Luchemos por la Vida as “the main player working in Argentina as regards to traffic safety public campaigns and education”.

- The European organization “*International Road Safety Prevention*, PRI, reported the courses for people who are renewing their driving license to be an example of a good practice for improving road safety.

- **The Road Safety Leadership award** given by ASIRT “for its dedicated efforts to protect the lives of travellers on the roads of Argentina” received in June, 2001.

- In relation to the leading position of Luchemos por la Vida on the traffic safety problem is interesting to surf the Internet where our association is mentioned around 3900 times.

  - Our web-site [www.luchemos.org.ar](http://www.luchemos.org.ar) receives an average of 18,000 visits per year.

**Conclusion**

Over and above what still needs to be done, we understand that this comprehensive and multiple approach deserves to be continued, taking into account results, and has to be deepened and considered when the time comes to plan actions.

Even though we know that “technology, infraestructure, legislation and enforcement must be subservient to adequate behavior (Huguenin, 2005), according to the acceptance that the human error is impossible to be totally eradicated in traffic”, we think the time of educational and awareness intervention is not over. Nevertheless, it is required in developing countries to build up, as the World Health Organization says, “a new traffic safety vision with a more interdisciplinary and integrative approach, thorough intersectorial collaboration, targeted policies and national action plans”. And non governmental organizations, as Luchemos por la Vida, can play important rolls on that.

But we also know that our role, from “The Third Sector” of our society, as a pressure and influence element in our community, and as mobilizers and social actors, cannot be delegated to others. That is why we do not give up in spite of many difficulties, and keep dreaming of the day in which God willing, no one will die in a traffic accident in Argentina, or in the world.
* The number of deaths in Argentina was computed at the time of or as a result of the accident, within the 30 days following, according to the most generally accepted international criteria. The numbers given are the most recently obtained (official data, mostly given by the Police or Municipalities). As many of the original figures only include deaths at the time of the accident, those were adjusted according to the internationally accepted rates, in order to obtain a serious appraisal, study and comparison of mortality in road accidentology in Argentina.

**This is in proportion to losses in other countries, for instance USA, $230.6 billion in 2000 (NHTSA, 2000 and Rune Elvik, 1991).**

References


- Luchemos por la Vida figures. Website: www.luchemos.org.ar


ABSTRACT

Austroads, the association of road and transport agencies in Australia and New Zealand, has produced a new series of national guidelines across a wide range of practices in road and transport management. The suite of Austroads guidelines is outlined, and this paper discusses current developments in guidelines related to road safety engineering. Topics covered include road design, traffic management, crash investigation and countermeasure development, road safety auditing, human factors and transport planning. This guidance is discussed in the context of the safe road system concept which acknowledges the need to design and manage the road environment to cater for road user behavioural capabilities and limitations, and injury tolerance. The issues addressed by ARRB in developing the technical content of the guidelines are discussed. These include incorporating relevant research results, technological developments, practitioner experience and new strategic directions. The forward program for review and revision of the guidelines includes identifying issues for which further research investigation is needed to improve their technical content. These issues and current related research projects are outlined. Issues relating to publication and dissemination of guidelines are also examined, including the potential for developing website portals to facilitate their uptake by practitioners in state and local government authorities.

1 INTRODUCTION

Austroads is the association of road and transport authorities in Australia and New Zealand, including representation from the Australian Local Government Association. Austroads funds and manages the production of national guidelines across a wide range of practices in road and transport management. The guidelines provide a basic reference for road authorities and seek to promote national consistency and harmonisation. They represent an agreed approach to the work road authorities undertake in relation to the road network. Austroads member organisations have agreed to adopt Austroads guides as the basis of their operation.

Austroads has recently developed a comprehensive library of revised guides which cover the design, construction, maintenance and operation of the road network for use by its member road authorities. ARRB Group was engaged to manage the development of these publications.

Safety is one of the key strategic program areas for Austroads, and a particular focus is given to engineering management of the road infrastructure for safety purposes. The present paper outlines the development and dissemination of technical guidelines in this area.
2 GUIDANCE IN TRAFFIC SAFETY
Much of the established Austroads guidance on road safety was found in a range of separate documents. Those primarily concerned with traffic engineering and management, and road design issues, included some advice on safety. There were also separate guidelines on road safety audit, urban and rural road design, and technical reports on specific related aspects such as travel demand management.

Such dispersed guidance is typical of the development of the material over many years and reflects the challenges of keeping up with and integrating new research results and emerging strategic issues.

Following a review of its strategic program, existing guidelines and associated technical documents, Austroads embarked upon a widespread revision of guidelines - to update them and align with the revised strategic program. The new series of guides covers the following subject areas:

- Asset management
- Bridge technology
- Pavement technology
- Project delivery
- Project evaluation
- Road transport planning
- Road tunnels
- Road design
- Road safety
- Traffic management

With the exception of the guide for road tunnels (due for completion in 2010) the new series of guides has been launched. They are released on the Austroads publications website (Austroads 2009). These guides will form the basis for the operation of Austroads member authorities, and each State has undertaken to pursue a transition program for adopting them.

The last three guides listed above are the guides of primary relevance to safety engineering of the road and traffic environment, and are discussed further in the present paper.

3 SAFE SYSTEM APPROACH
Approaches to improving road safety in Australia and New Zealand are guided by Safe System principles, which fundamentally involve making the road transport system more accommodating of human behaviour, while acting to minimise the contribution of that behaviour to road crashes.

The Safe System approach has been espoused by the Austroads member authorities and it is a central theme of the Australian National Road Safety Strategy (ATC 2008). The general goal is to provide safe travel for all road users by minimising the risk posed by the interacting elements of the road transport system.
The approach aims to provide a safer road and traffic environment through –
- safer speeds - speed limits which are appropriate for the function and construction of the road, terrain and adjoining land use.
- safer vehicles - vehicles which have improved functional design and protect occupants through structural design and protective equipment.
- safer roads and roadsides – identifying and treating sites with adverse crash histories or inherent safety deficiencies.

The basis of this approach recognises that there are limits to which the human body can tolerate forces generated in a crash. The central consideration is to ensure that road users are not exposed to greater physical forces than they can withstand without serious injury. In principle, this may be achieved in several ways, most obviously by reducing speeds. However, to rely on speed reduction alone would require very low speeds, possibly lower than the public would be prepared to accept. In practice, the goal of tolerable forces is sought through a combination of measures – for example, improved crashworthiness and protective equipment in vehicles, along with protective barriers to deal with run-off-the-road crashes, in a suitably managed speed environment.

Under this framework, the essential tasks of road safety management are:
- determining the relevant risk factors in a given situation;
• determining which risk factors can be effectively manipulated, via preventive or remedial action;
• determining which countermeasures will produce the desired outcomes, then applying them effectively.

The framework can be used to guide overall policy settings (e.g. speed limits for roads with a particular function, given the characteristics of the vehicle fleet in terms of occupant and pedestrian protection), and can be applied at the level of individual projects (e.g. determining the most suitable type of barrier, given the characteristics of the vehicle fleet and the estimated operating speeds at a particular location).

The Safe System approach has direct parallels with the Vision Zero concept pursued in Sweden and the Sustainable Safety approach being implemented in the Netherlands.

4 SAFER ROAD ENVIRONMENT
Providing a safer road environment involves application of road design and traffic management principles with a clear safety focus. Road engineers and managers have a prime responsibility for addressing the safety factors related directly to the road environment itself. They should ensure that it is designed and managed from a safety perspective, and that its operation is adequately monitored and measured.

Traffic management systems and facilities are required for road users to control their vehicles safely within the road space and in response to other vehicles and road users. Therefore, traffic managers and road designers need to understand some of the perceptual and information processing capabilities of drivers so that roads and traffic management systems may be designed to assist drivers in their task.

A safe road environment can be defined as one which provides an adequate level of warning, information, guidance, and control for all road users, with no surprises, and a roadside that is free of undue hazards. A safer road environment can be achieved through improvements in the design, construction and development of the road network, and in traffic management, so that driver behavioural needs are met and their capabilities and physical tolerance to serious and fatal injury are not exceeded.

It is necessary to ensure that the road design and its associated traffic management facilities are fundamentally safe before the road project is built, and by correcting problem locations in an existing road network as they are identified. Practitioners should ensure a safer road environment from both the macro perspective (the safety performance of the road network - or of specific road types within the network) and the micro perspective (the inherent safety characteristics of road sections). These approaches involve adopting fundamental concepts such as safety auditing, network risk assessment and remedial ‘countermeasure’ treatments. An analytical and structured approach is required, involving application of the discipline known as road safety engineering (Ogden 1996).

5 ROAD SAFETY ENGINEERING
Road safety engineering can be considered as the application of traffic and road engineering practices with the aim of preventing crashes and managing risk to an acceptable level. It is an augmentation of basic road and traffic engineering expertise.
It can be defined as applying the principles of road and traffic engineering, based on a sound analysis of all relevant data, with an understanding of road user behaviour and injury tolerance, to identify and implement improvements to bring about cost-effective reductions in crashes and casualties. It should apply at all stages of road/transport development – for example, in the planning of new developments, in the design of new roads, in safety improvements for existing roads, in remedial treatments of hazardous locations, and in routine maintenance programs.

Road safety engineering requires that the road network, and any additions or modifications, be examined and managed in a systematic manner to ensure that the elements of a safe road environment are provided.

Road safety engineering also gives effect to the Safe System philosophy that one should aim to provide a road network or system which does not kill or unduly injure the users of the system.

A basic objective in road safety engineering is to ensure the road network presents a consistent environment to road users. A consistent road environment, in terms of appearance and control features (road design and traffic management), assists road users in their decision making and behavioural responses.

6 RISK MANAGEMENT
Central to successful provision of a safer road environment is the risk assessment approach, and applying the concepts of risk engineering and management. This involves managing – and reducing - the risk of serious injury presented to road users by the road and traffic environment.

Risk management is addressed in Australian/NZ Standard AS/NZS 4360 Risk Management (Standards Australia 2004) which presents generalised guidance on managing risk. Risk can be expressed as a function of three primary elements, namely:

Risk = f (Exposure x Probability x Outcome)

In the road and traffic context these three elements can be identified as follows:

- **Exposure.** The number of vehicles or people travelling past or through a particular point on the road; typically the traffic volume.
- **Probability.** The likelihood that anyone at any time or point on a road initially loses control.
- **Outcome.** An array of possibilities arising from an initial loss of control; can range from a null outcome where a driver regains control to serious injury or death.

A safer road environment (one with a lower risk) can be achieved by reducing exposure and/or the probability and/or the severity of any crash outcome. If the outcome is expressed in terms of crash types (for which cost data are available), risk can be expressed in terms of cost.

The concept of the energy damage model in risk engineering - the concept that energy exchange can cause damage – leads to the following approaches for controlling energy and managing risk in the road environment:
• Managing speed.
• Maintaining control.
• Separating conflicting elements.
• Protecting road users.

7 SAFETY MANAGEMENT STRATEGIES
A road environment must meet basic objectives of mobility, efficiency, safety, and amenity. The basic intended outcome of a road environment safety program is a safer road and traffic environment through greater consideration of safety issues in the planning, design and development of the road network and traffic management facilities.

The important strategic approaches can be listed as follows:
• Ensuring safety in planning and design – adopting a road safety assessment concept in planning (safety conscious planning) and the road safety audit procedure as a fundamental component of the design process.
• Treating known hazardous locations – pursuing specific treatment of deficiencies at locations with undue crash experience, using remedial ‘countermeasures’ treatments which address the particular nature of the crash experience identified.
• Identifying safety deficiencies in the road network - strategic monitoring of the road network, applying a safety risk assessment system to measure and analyse the demonstrable and intrinsic safety aspects of the road network, as a road assessment program.

Underpinning these strategies is the fundamental practice of consistently applying relevant standards and guidelines.

8 MANAGING THE ROAD ENVIRONMENT
Managing safety in the road environment means managing the risk that injury will occur, whether it arises from the behaviour of road users, the performance of vehicles or the characteristics of the road environment. Making roads safer means reducing the risk.

Fundamental principles for managing safety in road design, traffic management, and remedial treatment practice include -
• speed management (aiming to limit kinetic energy in the road traffic system, so that human injury tolerances are not exceeded when crashes occur),
• conflict management (aiming to control manoeuvres at locations such as intersections, or where pedestrians are prevalent, to avoid conflicts and reduce crash risk),
• hazard management (removing or treating hazardous obstacles in the road environment so that injuries from crashes are contained within survivable limits),
• road user information management (ensuring an adequate, clear and timely release of information through signals, signs and markings to guide road user decisions and behaviour)

The various road design elements and traffic facilities of the road environment have the potential to influence the safety of traffic operation within that environment. These elements include road alignment, cross-section, pavement characteristics, roadsides, and intersections. The tools of traffic engineering (traffic controls, signals, signs, markings, delineation and road lighting) are applied in seeking to provide the warning, information, guidance, control or clearance necessary for a safer road environment.
Traffic control and management at roadworks is an essential component of network safety management. The immediate environment of roadworks sites needs to meet basic safety characteristics for protecting workers on site and for providing warning, information, guidance and control for approaching road users.

9 DEVELOPING THE GUIDELINES – TECHNICAL BASIS
Much relevant information and guidance aimed at achieving a safer road environment is incorporated in various guidelines and standards. These are based on many years of research into the safety effectiveness of road design features and traffic management initiatives, and on the consolidation of acknowledged best practice.

Following guidelines alone does not always guarantee an acceptably safe road environment. There is a need to ensure that the road and traffic environment is also assessed specifically in terms of its potential and actual safety performance.

Each of the new Austroads guides has been developed under the direction of a task force or review panel comprising senior technical representatives of the Austroads member agencies. The development of the guides involved reviewing and updating the existing guides and related technical documents, incorporating new strategic directions, relevant research results, technological developments, and practitioner experience.

ARRB Group was responsible for managing the authorship and drafting of the documents and was able to draw on research results through its extensive road transport library resources, plus its own research experience over several decades, to contribute directly to updating the material in the guides. The following issues were addressed in preparing the guides:

- Strategic initiatives – ensuring the Safe System principles are properly addressed and incorporated, to encourage adoption of the Safe System approach as the fundamental concept underpinning the contemporary approach to road management in all its aspects, especially design and traffic management.

- Relevant research findings – incorporating the results of research projects, many of which were undertaken for Austroads strategic programs on safety engineering, network management and technology.

- Technological developments – incorporating descriptions of recent and emerging technologies, including the potential for ITS applications, in areas such as traffic survey techniques, traffic monitoring and data acquisition, electronic variable message signs, and intelligent speed assistance systems.

- Practitioner experience – collating information on road design and traffic management practice and safety initiatives implemented by member jurisdictions, and incorporating the results of successful experience into the guides.

10 ROAD SAFETY ENGINEERING GUIDANCE
In the new Austroads guides, those primarily related to road safety engineering are the Guide to Road Safety, the Guide to Traffic Management, and the Guide to Road Design. The contents of these three Guides are outlined in Attachment A.
The Guide to Road Safety provides both general guidance on road safety issues and a comprehensive treatment of the basic building blocks or engineering tools for application in managing the road environment. Some road safety aspects are also covered in the context of specific road design and traffic management practices in the two companion guides.

Additional safety guidance is given in a part of the Guide to Traffic Management entitled Road Environment Safety. It provides information and advice for practitioners concerned specifically with the road safety aspects of traffic management in the road environment. It considers the role of traffic management in influencing road user behaviour, and in improving safety in the road, traffic and roadside environment. It summarises and draws together the safety-related building-block material in the two companion guides. The document has a primary focus on achieving safer operation within the road and traffic environment, through traffic management and traffic engineering practice. It presents material which:

- defines a safe road environment and the broad approaches for achieving it,
- describes the basic components of road safety engineering and its application in terms of risk engineering concepts, primary strategies and safety management systems,
- outlines the principles and practice of managing safety in the road environment, as related to fundamental features of the road infrastructure and the basic tools of traffic engineering and management.

There is extensive cross-referencing to specific sections within all three primary guides for detailed advice.

11 RESEARCH DIRECTIONS

A major challenge confronting road authorities is to determine how the principles of the Safe System approach can be implemented in practice. This is being investigated through ARRB’s current research program.

A pertinent stream of investigation includes identifying major safety issues as indicated by current data analyses. This has led to emphases on the following:

- speeding and its management,
- specific features of the crash situation in rural areas,
- maintaining initiatives in drink-driving and occupant restraint use, and
- pursuing the challenge of managing the driver fatigue problem.

An important aspect in the context of a safer road environment is to examine the involvement and management of road and roadside factors in crashes. A basic task here is to identify and implement initiatives to achieve a safer system with respect to road and roadside features.

With regard to the road environment, crash features of particular concern have been identified as follows:

- Rural crashes in which high speeds typically are involved,
- Crashes at intersections where side impacts have great potential to exceed human injury tolerance,
- Run-off-road crashes where roadside hazards have the potential to unduly increase the severity of injuries sustained, and
• Collisions between motor vehicles and vulnerable road users where human injury tolerance is readily exceeded.

The fundamental approaches to dealing with these issues must include:

• Reducing the extent of injurious energy in the system, namely typical impact speeds, and
• Reducing conflicts between road user elements, both vehicle-to-vehicle and between vehicles and unprotected road users.

There is a need to identify viable treatments which will:

• Reduce speeds and road features which contribute to high-speed crashes, especially head-on collisions; seeking to enhance the separation of opposing traffic streams;
• Reduce impact speeds on approaches to, and through, intersections; seeking to modify the design of intersections and the enhance traffic management techniques on their approaches;
• Reduce impact speeds with roadside objects; seeking economically beneficial approaches to providing improved delineation, roadside clear zones, and/or removing and protecting hazards;
• Avoid collisions with vulnerable road users; seeking techniques for better separation of participants and/or for dramatically reducing vehicle speeds in areas typically involved.

In practice, the Safe System approach must guide features such as road and intersection design, and treatments such as protecting roadside hazards with barriers, or physically separating vulnerable road users. These issues are being pursued in the current research program, in which there are many projects seeking to develop further the potential for practical implementation of Safe Systems. These include:

• Investigating the relationship between speed limits and road infrastructure, leading to a set of revised guiding principles for speed limit setting;
• Quantifying the effect of lower speed limits (for arterial and local roads) on network operations;
• Examining techniques to reduce speeds and speed related crashes in rural areas;
• Reviewing the effectiveness of roadside hazard management initiatives;
• Improving intersection safety by treating intersection approaches to achieve safer vehicle speeds through intersections

The findings from these investigations will be firmly aimed at answering the question: what measures or initiatives can realistically be introduced to achieve a safer road and roadside environment? There will be a need to examine the effectiveness, viability and feasibility of promising treatments, and a series of relevant field trials is envisaged.

12 DELIVERING THE KNOWLEDGE
A basic feature of the development of the new series of guides is the clear focus on electronic publication. All guides are released on the Austroads publications website, and are available for download in electronic format or for purchase in hardcopy. The website provides an
annual online subscription service and a 'RoadWatch' alert service where users can be advised of either selected or all new documents as they become available.

In addition to the availability online, arrangements for disseminating the guideline material include activities on behalf of Austroads as follows -

- a series of awareness seminars providing overviews of the scope and content of the new guides;
- training workshops where participants are introduced to specific topics or issues covered by the guides, including work with case studies and examples;
- opportunities taken to present summary material at conferences of relevant institutions.

A further means for disseminating the material contained in some guides is to incorporate it into specific online tools, by means of which users can apply the guidance directly to real practical cases. Examples of this development already exist in some software products now available. These include:

- Road Safety Audit Toolkit – a free online tool to assist practitioners to carry out road safety audits; steps users through the road safety audit process, provides Australasian and jurisdiction specific references, and allows auditors to generate road safety reports.
- Road Safety Engineering Toolkit – a free online reference tool outlining best-practice, low cost, high return road environment measures to achieve a reduction in road trauma; draws together existing road safety engineering knowledge, updated with recent experience from local and state government agencies, and with the results of comprehensive road safety research reviews; a similar tool is being developed for applying the road assessment program approach in the international sphere (iRAP).
- NetRisk – a process for road authorities to assess the safety conditions of a road network; can be configured to detect a manageable number of hazardous locations in a budgeting period; uses a set of trigger points to prompt investigation of hazardous sites when they exceed minimum preset safety levels; involves completion of a network level risk assessment to focus attention upon high risk sections of road, followed by deeper investigation of the high risk sites to locate specific hazards and preferred treatment options.
- Road Safety Risk Manager – for assessing and ranking road safety audit recommendations, mass action programs of work, safety related routine maintenance issues, design audit recommendations, or responding to road safety issues raised by regular inspection programs; enables comparison of crash risk at a site before and after the implementation of a given treatment.
- XLIMITS – a knowledge based software system to help in consistent and appropriate setting of speed limits, based on existing speed management and speed limit setting processes; can be tailored to meet specific needs of jurisdictions, and has been applied in Australia, New Zealand and USA.

Further information on these tools is available at ARRB (2009).

The application of such tools by road authorities, and thereby the adoption of the underlying recommended practices or processes, might be inhibited by lack of awareness, understanding, or resources, and perhaps the perceived inability to adapt the material to meet special procedures for some jurisdictions. Readily accessible workshop activities are therefore
important, and there is potential for developing further software assistance to help tailor
guidance material to the particular requirements of individual jurisdictions.

13 REFINING THE GUIDANCE
Guidelines are necessarily living documents, and an important consideration is the ability to
keep them up-to-date and to ensure they are truly reflective of acknowledged best practice.
An effective process is therefore required for undertaking reviews of the guides according to a
schedule prioritised in terms of the implications from recent research findings, technological
developments or emerging strategic issues and directions.

The research program outlined above is aimed at providing further evidence and guidance for
inclusion in future editions and revisions of the Austroads guides.

The electronic publication approach adopted for the Austroads guides facilitates the following
tasks:
- eliciting feedback from a range of practitioners across both government and private
  industry (including via relevant professional institutions), primarily on the basis of
  using the guidelines in practice - the Austroads publications website has a facility
  whereby users can provide this feedback;
- incorporating at short notice any necessary changes arising from research,
technological developments or other issues;
- effecting the necessary amendments to the documents, and managing the cross-
  referencing between guides;
- release and circulation of the amended guides.

A Glossary of the terms used in Austroads guides has been produced to ensure consistency in
the terminology used across the parts of various guides. There is one glossary covering all
guides, with the objective to ensure that terms used have consistent meaning. The glossary
includes terms and definitions relevant to Austroads members and others involved in the road
and transport industry. Where terms may have different meanings in different contexts this is
indicated in the glossary. The terms and their definitions are under continual review and new
terms and definitions will be included as necessary, through regular updates. The glossary is
accessible via the Austroads publications website.

The electronic versions contain hypertext linkages (and search facilities) to specific topics
within a document. It is intended that eventually there will be full electronic linkages
between all documents, which will help in accessing and following the many cross-references
that typically arise in a subject as multi-faceted as road safety engineering.
There is potential here for augmenting the general glossary document to provide an on-line
electronic directory to specific topics, which could be developed to form a portal to the
information contained in all the guides.

14 CONCLUSION
Safety is one of the key strategic program areas for Austroads, with a particular focus on
safety engineering of the road and traffic environment. This has been addressed during the
development of a new series of guidelines for road authorities, and seeks to reflect the
contemporary safety management approach of integrating safety considerations into the
practice of road design and traffic management. Technical guidance in the emerging
discipline of road safety engineering has been provided through revision, and some
consolidation, of guidelines and other technical reports in those primary constituent disciplines.

Successful implementation of the Safe System approach will depend upon further investigation and identification of viable initiatives that can be realistically introduced to provide a safer road and roadside environment. ARRB is pursuing this through its current research program, much of which is being undertaken directly for Austroads.

REFERENCES
Australian Transport Council (2008), National road safety action plan: 2009-2010, ATC, Canberra, ACT.

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ATTACHMENT A – CONTENT OF AUSTROADS GUIDES RELATED TO ROAD SAFETY ENGINEERING

Each of the following Guides comprises several Parts, the contents of which are summarised in the lists below.

The **Guide to Road Safety** covers the following topics:
- *strategy and evaluation* – an overview of past road safety plans and essential processes, evidence-based approach, strategic partnerships, setting realistic goals, monitoring and review;
- *speed limits and speed management* – the function of speed limits and their relation to road hierarchy, setting speed limits, time-based speed limits, signing and marking, and speed management;
- *local government and community road safety* – the role of local governments and communities, strategic partnerships and capacity building, developing a road safety strategy, funding, mobilising resources, implementation, case studies, monitoring, evaluation and review;
- *rural and remote areas* – special considerations in rural and remote areas, fatigue management, community road safety programs, road design and delineation, tourist and directional signing, incident detection and patient retrieval;
- *road safety audit* – principles, procedures and checklists for safety assessment;
- *road network crash risk assessment and management* – road authorities’ responsibility for managing risk, principles of risk management applied to a road network;
- *treatment of crash locations* – identification, countermeasure development, implementation and evaluation of remedial treatments;
- *roadside hazard management* – identification of roadside hazards, clear zone theory, delineation, hazard treatments.

The **Guide to Traffic Management** covers the following topics:
- *traffic theory* - characteristics of traffic flow; theories, models and statistical distributions; basic descriptors of traffic flow relationships, vehicle interactions in traffic, queuing theory, gap acceptance theory;
- *traffic studies and analysis* - traffic and transport data collection surveys and studies; traffic performance of roads and intersections; traffic analysis for mid-block situations, signalised and unsignalised intersections, including roundabouts, road capacity analysis;
- *network management* - broad strategies and objectives of managing road networks to provide effective traffic management; operational objectives, performance measures, network management plans; needs of freight, public transport, pedestrians, cyclists and private vehicles;
- *road management* - traffic management issues applying to a road sections, road space allocation, access management, lane management, application of speed limits;
- *intersections, interchanges and crossings* - traffic management at locations where different traffic and road user streams intersect, selection of intersection types, signalised and unsignalised intersections, roundabouts and interchanges, rail crossings, pedestrian and bicycle facilities and crossings;
- *traffic management in activity centres* - principles for the planning and traffic management of activity centres and associated transport nodes; commercial and civic precincts, tourist and sporting centres, intermodal transport interchanges;
• **local area traffic management** - systematic approach for local areas, application and effectiveness of traffic control measures on an area-wide basis, planning design and implementation issues, community participation, selection of schemes, treatments and devices;

• **traffic operations** - operational matters relating to traffic management on road networks, traffic signal systems, congestion management, incident management, management of transport information, operational management of road space, systems integration and interoperability;

• **traffic control and communication devices** - design and use of traffic control and communication devices, signing and marking schemes, traffic signs, static and electronic, pavement markings and delineation, traffic signals and islands;

• **parking** - parking demand and supply, parking policy framework, implementation of on-street and off-street parking, parking controls in urban centres, park-and-ride facilities, electronic parking guidance systems and signing;

• **traffic impacts of developments** - processes for assessing traffic and transport impacts of land use developments, policy and planning considerations, development profiles and issues, traffic impact assessment, developments and access management.

• **road environment safety** - approaches to ensuring a safe road environment through traffic management, the role of road design and traffic management in providing road and roadside safety.

The **Guide to Road Design** covers the following topics:

• **design process** - philosophy and principles of good design; range of influences, information, data, criteria, and other considerations that may have to be considered in developing a road project;

• **geometric design** - detailed information necessary for developing coordinated road alignments that allow safe operation of the design traffic; cross sections, sight distances;

• **intersections, interchanges and crossings** - rural and urban situations, signalised intersections, roundabouts, pedestrian and cyclist crossings;

• **drainage design** - road drainage systems, environmental factors, stormwater runoff, local planning requirements;

• **roadside design** - median strips, road furniture, utility services, roadway lighting, pedestrian and cyclist facilities, landscaping, noise attenuation, rest areas, roadside safety, safety barriers;

• **geotechnical design** - geotechnical investigation, earthworks design, construction materials, environmental issues;

• **documentation** - efficient and comprehensive design documenting of decision making process, quality management.
ABSTRACT
Each day 3,000 people die in road accidents worldwide, a number comparable to the total number of victims of the 9/11 terrorist attack in New York. Each year the death toll is enormous: nearly 1.3 million road deaths and more than 10 million people injured suffering life-changing physical and emotional injuries. The situation is specially difficult in Poland were the road accidents figures are among the worst in EU. For these reasons it was absolutely necessary to conduct a comprehensive and in-depth study in Poland on the life of accident victims and their families. We had to have the data to establish how accidents affect people’s lives and the quality of life. What is the victim’s view on the work of the courts, how do government institutions and insurance companies deal with the claims and what help is in fact available from the authorities, organisations and institutions established to help accident victims and their families.

Department of Highway Engineering, author of the National Road Safety Programme GAMBIT 2005 in Poland, had been preparing to this broad study for a few years and in 2007, thanks to the financial support of the ZEUS Project, we got finally the possibility to carry out the survey. The comprehensive study involved the victims, their families and non-governmental organisations that help accident victims. In this paper we would like to present the assumptions, the methodology, the organisation, as well as the results of the research. The results are very valuable for us and we are convinced that this would be equally interesting for experts from other countries as the consequences of road accidents affect every victim and his/her family.
1 INTRODUCTION

Everyday some three thousand people die in road accidents worldwide, a figure comparable to the number of people killed in the terrorist attacks in New York in September 2001. Annually this is almost 1.3 million road deaths and 10 million injuries. The World Health Organisation estimates that per one statistical fatality there are four people injured who will remain disabled for the rest of their lives, ten people are hospitalised and as many as thirty need ambulatory care (WHO, 2004). In 2008 in EU27 road accidents claimed 39,000 lives which in public health terms is 7.8 killed per 100,000 population. Poland with its rate of 14.7 is sadly the last but one among European Union countries in terms of road user risk exposure. The rate in the best performing countries is below 5. In Poland the annual number of road deaths is 5,500 and 50,000 people are injured. Everyday 15 people die and 180 are injured with some of them disabled for the rest of their lives. Everyday the casualties of road accidents fill up an average sized hospital (more than 100 beds).

Using databases of deaths and injuries from accidents, it is estimated that each year in Europe more than 200,000 people become part of the huge number of road accident victims and their families from the years before. What we do not know from these numbers is how this has affected the victims and their families. We cannot establish the seriousness of the injury or its consequences. We know very little about the costs and quality of treatment of accident casualties. We do not know the cost to the entire health care system. And we know just as little about the trauma and problems of the victims directly after the accident when faced with a situation they have never been in. Consequently, we cannot make a factual assessment of how road accidents affect the lives of victims and their families.

Over the last thirty years more than ten European countries have introduced safety policies that have helped and are still helping to reduce number of accidents. Sadly, some countries are still not addressing these problems properly making their citizens pay an ever-increasing price of mobility. As a rule, the less is done to improve road safety, the worse it gets for accident victims and their families. Successful road safety policies, on the other hand, have always made the social cost of road accidents the focus of all measures. This cost includes the loss borne by the society that is the loss of those involved in the accidents, cost of technical and medical rescue, police and judiciary and the costs of treatment and rehabilitation. The loss is not only economic; it is also the psychological effect it has on the victims and their families.

Because estimating the costs and in particular the social cost is not easy, it is hardly ever done. It is the “moral loss” that is most difficult to valuate in money terms. One of the few research studies in Europe is a study carried out by the European Federation of Road Traffic Victims FEVR (FEVR, 1996). Its objective was to identify the problems faced by victims of road accidents and their families and propose systemic solutions to stop the decline in the quality of life caused by road accidents.

Following up on the work of FEVR, the GAMBIT Foundation for Independent Road Safety Research undertook a similar study in Poland in 1998. Obtained from a preliminary sample of respondents, the results led to some general conclusions and were subsequently used to prepare a new survey. Because they were promising, the results attracted the interest of the Polish
Commissioner for Civil Rights Protection who initiated in 2002 a national conference “Situation of people affected by road accidents” (Krystek, Oskarbska, Żukowska, 2002). The conference showed that there was a great deal of interest in the survey both among road safety professionals and road accident victims. With so much interest in the problem, new efforts were undertaken to obtain funding for further work. In January 2007 the minister of science awarded the Gdansk University of Technology a grant to run a three-year project to develop a proposal for an integrated system of transport safety in Poland. Called ZEUS, the project has funding for a study of “transport accidents as a public health problem” including the study of accident victims and the costs of treatment. This paper is the result of the study.

2 WHAT WE KNOW

A study of literature shows that comprehensive research into the decline in standards of living of accident victims and their families has been quite scarce and that the analyses would usually (mainly) look at methods of estimating road accident costs for further CBA analysis (Cost-Benefit Analysis). As an example, the United Kingdom established that the total loss caused by road accidents is about 18 billion pounds annually with the costs per victim:

- 1.6 million pounds – fatality,
- 190,000 pounds – severe injury,
- 20,000 pounds – slight injury.

Used mainly for analysing the economic effectiveness of road projects or other road safety measures, the data do very little for the actual issue which is to evaluate how road accidents affect the lives of victims and their families.

One of the best known studies of accident victims is the FEVR study mentioned above (FEVR, 1996). Other important studies include work carried out in France (Alfaro, Chapuis, Fabre, 1994), United Kingdom (Abdalla, Barker, Raeside, 1997), Sweden (Hasselberg and Laflamme, 2005; Yahya, 2001), Canada (Bagley, 1992) and the USA (Baker et al, 1971). The social consequences of road accidents were also studied in Norway. The objective was to evaluate the effects of the accident on the day-to-day lives involving such activities as getting dressed, household chores, cleaning or shopping. Another study looked at the effect of traffic accidents on anxieties, loss of concentration and poorer memory (Haukleand, 1996). The purpose was to describe the effects of accidents on the post-traumatic-stress-disorder (PTSD).

The following are the conclusions from the studies of literature, analyses of survey results (ETSC, 2007; FEVR, 1996) and experience of people working to improve road safety.

Court proceedings:

- In their assessment of the criminal proceedings people are most dissatisfied with how quickly the investigation is conducted. The victims and families believe that it is much too quick, possibly leading to a mild punishment or no punishment at all. There are frequent complaints about unprofessional case handling, expert opinions, disrespect for the victims and their families. One of the most common demands is to have another blood test conducted of the person who caused the accident to establish if they had been drinking (or taking drugs) and driving.
- Families of dead victims demand a thorough investigation just as in homicide cases.
- Families also demand that the person who caused the accident should have their driving license withdrawn until the court’s final decision.
Organisations helping accident victims are seriously questioning the courts’ liberalism in their decisions on cases involving causing a road death.

There is an increasing pressure on more severe punishments for repeat offenders such as a lifelong ban on driving.

**Damages:**

- The survey shows how critical the respondents are about the claims process.
- The majority of the respondents were dissatisfied with how they were treated by the insurer or how much money they were offered.
- Injured victims and their families demand that they should be paid at least a portion of the insurance immediately to cover the cost of funeral or treatment and allow them to lead a normal life without getting into debt or using the support of the family.

**Helping the victims:**

- More than half the victims say that the time from the accident until they have fully recovered physically and mentally is often more than a year.
- There is no proposed solution on how to solve the problem of recurring neurological problems after a head injury and after the insurance has expired.
- FEVR studies showed that accident victims suffering from neurological ailments said in the survey that they were doing slightly better than the families looking after them.

**Decline in quality of life:**

- Most families of dead victims say they started taking sedatives after the accident, smoke cigarettes or take drugs. This leads to a direct risk, if the person uses traffic or indirect risk if the family relations deteriorate.
- Losing a job or having to change jobs for the worse or one that pays less causes serious consequences for the family. This means a lower standard of living and will usually affect housing standards or the children’s school.

### 3 RESEARCH GOAL AND METHODS

Although scarce, the studies and estimates show that families of people killed in a crash and people who became disabled in an accident and their families experience a dramatic decline in the quality of life. Because more and more people are affected each year we believe that this should be addressed by the government who must take systemic decisions. But before we can get the interest of politicians in what happens to accident victims, we need to answer the basic questions. What do we really know about life after an accident and what effect has the accident had on the victims’ and their family’s lives? In fact, we know very little about what happens to a family who loses their only bread winner. What happens to a family whose life after the accident is all about looking after their relative who can no longer do even the simplest of tasks. And even if the victim can use a wheelchair, what chance do they have of overcoming the physical barriers such as stairways, thresholds or curbs.

The survey described in the paper was looking for the answers. The main difficulty was establishing contact with the victims and their families. The contact had to be made at least one year after the accident which was long enough to get reliable answers about what had changed in the lives of the respondents as a result of the accident. We were not able to get the contact directly form the Police files because of the law on protection of personal data being in force in Poland. It was a serious obstacle. To solve this problem we decided to publicise our research idea.
in the media to attract the interest of potential responders (road accident victims and their families) but it turned out that it did not bring the desired results. We received very few replies. Therefore to overcome the difficulty of establishing contact with the victims, in the next step, we started cooperation with a Polish non-governmental organisation (NGO) that helps accident victims called “Alter Ego”. The NGO provides legal assistance to accident victims and they have a full data basis on their clients (about 1000 addresses). Together with FRIL Foundation for the Development of Civil Engineering, originally the GAMBIT Foundation, they run the survey amongst the people they formerly helped.

The first step was to prepare a questionnaire with questions to get the answer on “How much has the accident affected the standard of living and the quality of the victims’ life?” Eventually, two questionnaires were developed; one was for the friends and relatives of people who died in an accident with 40 questions and the second was for victims of road accidents with 48 questions. Both consisted of six blocks of questions:

- general information (the year of the accident, what type of road user was the victim, sex, etc.)
- psychological and physical consequences of the accident,
- occupational and financial consequences of the accident,
- claims (were the victims able to get compensation, what kind of compensation)
- criminal proceedings (the victims’ opinions on the court proceedings)
- help after the accident (did the victims receive any help from the authorities that are established to help accident victims and their families)

While the questionnaire was designed to cover all the problems faced by victims of road accidents in Poland, we did not want it to be too long to discourage the respondents. This is why we consulted accident victims NGO’s (non-governmental organisation) after we prepared the first draft. We also asked the police, medical services, psychologists, sociologists and the victims to review the questions (Zukowska, Krystek, Popiel, 2008).

The survey was launched in 2008 with questionnaires sent by mail directly to the addresses of the respondents. The poor feedback we got was quite a surprise. We were all the more surprised because those people had already received legal help from Alter Ego and we expected some sort of support. We decided to follow a different route for contacting respondents and went to hospitals to talk directly to accident victims when they came in for a checkup a year after the accident. So far we have had 51 responses from families of people killed and 161 from victims or their families, altogether a sample of 212 responses. Although we used different surveys for the two groups of respondents, given the size of the sample and for the purpose of the discussion we only chose those questions that were repeated in both questionnaires.

Because the questionnaire is quite long and we did not get many answers, it is worth saying that this report is only a small part of the complete final report. We are quite happy to quote the results of other surveys, especially when we clearly get the same answer.

4 OVERVIEW OF SELECTED RESULTS
First finding from the received answers to the questionnaire was that access to information is very poor. Similar to the study by FEVR 90% of families of people killed and almost 80% of people injured complained about not being told about their rights, such as the right to ask questions, victim representation, the right to a post-mortem or the time for filing appeals. Please note that most of the respondents came from small towns. Every third person came from a town with less than 5,000 population. This is consistent with the amount of income which was less than PLN 1000 ($1 = PLN 3) in 45% of the cases. This suggests that the respondents’s access to information about formal and legal procedures was difficult. Neither could they afford to pay for the information themselves. This links in to the question about additional costs for private treatment, which the respondents had to pay out of their own pocket.

This leads to the problem of support for accident victims at a time when they only have limited income or no income at all. The support usually comes from the family (37%), friends (21%) and doctors (12%). This help is very much needed because after the accident every third respondent lost their job. The seriousness of the problem is underlined by the fact that every third respondent was the head of the family. Loss of income is another loss caused by a road accident. 17% of the respondents lost ¼ of their income and as many as 24% lost half of the amount the family had before the accident. As many as 60% of the respondents lost more than half their earnings.

Procedures for obtaining compensation are one of the most difficult stages of struggling with the consequences of an accident. The most heavily criticised procedures include those involving health assessment. As many as 77% of the respondents said that they had suffered most harm from doctors assessing loss of health. In addition 68% said that the damages were paid after 30 days. Families who lost their loved ones were dissatisfied with nearly all the issues listed in the questionnaire. More than 50% of the respondents claimed that court procedure took more than a year. In the end 67% of the respondents were not awarded any damages for the death of the victim and 96% found the damages unsatisfactory. 88% of family members of fatalities started taking medication, a clear proof of the trauma they had been through.

The respondents were very clear about their views on three issues regarding criminal proceedings:

• As many as 63% of the respondents did not exercise their right to see the case files during the damages case.
• As many as 65% of the respondents stated that the person who caused the accident should be given an additional sentence of a lifelong ban on driving.
• More than half of the respondents said that the accident has made them more careful in how they use traffic.

Although this is just a small sample of the possible consequences of road accidents, it gives us a good idea of the difficult situation of the victims and their families. What should follow from the analysis are specific recommendations and changes to help the victims cope with the difficulties they have to go through in Poland. They show that the families need first and foremost:

• someone who has the professional background and knows how to inform people about the death of a loved one;
• immediate and continuous help of a friend and psychologist;
• direct access to the body of the person diseased;
• clear information about their rights, investigation procedures, organisations of accident
  victims, a full account of the accident;
• professional legal help.

5 CONCLUSIONS FOR THE SYSTEM IMPROVEMENT
Road accidents are one of the main health problems in Poland. It is the huge number of victims
and the length of time during which they have to endure the consequences. The problems faced
by the victims deteriorate the quality of their lives. Considering the fact that it is the victims
themselves and their families, the suffering affects a huge number of the population. Sadly,
because we know so little about the nature and weight of the problems that victims struggle with
in Poland, the problem is very much neglected by the authorities and the public.

Studies into the lives of accident victims in the ZEUS project have shown the scale of suffering
and decline in the quality of life of the population caused by accidents. What the study shows is
that both the public and the government and first of all our legal system fail to understand how
many people are affected when they lose their parents or become disabled. The harm is just like
in the case of victims of violence. While the outcome is the same, the perpetrators of these
tragedies are subject to completely different procedures when they are punished for causing an
accident involving a death.

The questionnaire emphasised the legal side of the problem in the belief that the assessment of
the claims procedure, criminal procedure and help after the accident should encourage legislative
proposals to help accident victims and their families. Below is a general overview of the
legislative changes that must take place to address the problems of road accident victims in
Poland:
• medical rescue act (the current act should be changed according to European standards)
• changes in the code of criminal procedure to allow non-governmental organisations to
  become involved during pre-trial proceedings,
• a verification of experts analysing road accidents and making them responsible for
  negligent opinions,
• it is in accordance with the civil code and logic to make insurance companies of those
  who caused the accident pay the standard costs of treatment, rehabilitation, etc. and
  damages, including disability pension. That way the public will not pay for the crime and
  the victim will be ensured a full and optimal care. In addition, the Social Security will not
  have to pay the significant and unjustified costs of damages for road accident victims and
  commercial companies will increase their interest in preventive measures.
• centres should be established to provide care to chronically ill victims of road accidents.

We hope that the results of the questionnaire will trigger the process of introducing significant
legislative changes in Poland to help accident victims. We are also hopeful that we will be able to
encourage the Polish Parliament to adopt the Health and Life Protection Act (GAMBIT’98) after
10 years of our efforts.
REFERENCES
ABSTRACT

Even though the traffic fatality risk (fatalities per 100 000 inhabitants) in Tanzania is quite low, the fatality rate (fatalities per 10 000 vehicles) is one of the highest in the world. With increasing vehicle density this means that the number of people dying in traffic will increase dramatically in the near future. Therefore it is important to implement measures to increase traffic safety as soon as possible, and in order to be able to do this in an efficient way, it is important to investigate where the main problems lie.

Within the EU project ASSET-Road a questionnaire study on road safety was conducted with 250 truck drivers in Tanzania. The study was done to increase the knowledge about the situation of the Tanzanian truckers, who are the most frequent road users in the country. The drivers were interviewed in three different towns in southern Tanzania, and participation was voluntary. The questionnaire treated demographics, the state of the drivers’ vehicles, the frequency of breakdowns and the maintenance of the vehicles. Further questions were concerned with driver behaviour, crash involvement, crash risk and crash mitigation.

The drivers who participated in the study were predominantly male, their average age was 36 years. Around 40 % of the trucks did not have any seat belts installed, with a larger share of older trucks lacking belts. Most of the drivers who had seat belts reported to use them, however. Almost 40 % of the drivers reported to have been involved in at least one crash, and 45 % of those drivers had experienced fatal crashes. This underlines that crashes counted per vehicle are very frequent, and the results are often severe, especially when heavy vehicles are involved. Truck drivers reported to drive 10.6 hours without break on average, with several drivers reporting that they had to drive 24 hours without rest. When asked what the three most common crash causes were, driver related causes were prominent. Drivers were said to be reckless, further causes named often were drunkenness, inattention and sleepiness. One of the most mentioned crash mitigation strategy was driver education, but also improvement of the roads and the vehicles. This indicates that countermeasures should be implemented in an integrated fashion, taking the aspects driver, vehicle, infrastructure, legislature and other road users into account.

1 INTRODUCTION

Even though there are comparatively few vehicles on the roads in Tanzania, the traffic safety problem should be a major public health concern. While in the 1990s highly motorised countries like Australia, the USA and Western Europe had around 60 % of the world’s motor vehicles, they accounted for only about 15 % of the population and fatalities (Jacobs, Aeron-Thomas, & Astrop, 2000). Africa, on the contrary, stood for 11 % of the global road fatality share, but only for 3-4 % of the global vehicle share. In the last decade the motorisation rate in Tanzania lay at around 5 vehicles per 1000 inhabitants, while in highly motorised countries this rate lies at around 500 vehicles per 1000 inhabitants or more, with the USA topping the list at almost 800 vehicles per 1000 inhabitants. Therefore, indicators like fatality rate, which is the number of fatalities per 10 000 vehicles, and fatality risk, which is the number of
fatalities per 100 000 inhabitants, differ immensely for countries of very different motorisation levels. With about 111 the fatality rate in Tanzania belongs to the highest in the world, while the most highly motorised countries have rates around 2 or below. The fatality risk, however, is approximately equal in Tanzania and those highly motorised countries with the lowest risk rates. It can be assumed that an increase in the motorisation level in Tanzania would lead to a large increase in fatality risk. Thum (2004) reports that for 2002 the number of registered vehicles per 1000 inhabitants lay at 14, which would be an almost 3-fold increase within only a few years. She states also that the number of motor vehicle crashes increased with 52 % between 1998 and 2002, and that the fatality risk lay at 6 in 2002. The official statistics report 1583 fatalities for 1998 and 2050 fatalities for the year 2002.

Generally the proportion of crashes with fatalities and serious injuries relative to the total amount of crashes is much higher in developing countries than in developed countries, because both the passive and active protection in the vehicle and in the infrastructure are much poorer in developing countries. Additionally, the medical treatment after a crash is much less developed.

A large difference between developing countries like Tanzania and highly motorised countries can be found in the distribution of fatalities over road user types. In highly motorised countries the most frequent victims are car occupants, with the pedestrian fatality involvement being usually a third to a fifth of that frequency. On the other hand, in Tanzania in 1995 it was reported that 6 % of the fatalities were drivers, 41 % were passengers, 40 % were pedestrians, and 11 % were bicyclists (Jacobs, et al., 2000). The numbers for 2002 are reported by Thum (2004) and lie at 41 % for pedestrians, 37 % for passengers and 14 % for bicyclists. It has to be noted that in Tanzania people often ride on pickups and trucks, therefore the number of passengers per vehicle is much higher on average than in highly motorised countries.

Rwebangira, Pearce and Maunder (1999) report the percentage of crashes and fatalities for vehicle type for the years 1997 and 1998. They state that even though the involvement of long distance buses in crashes in general lies at 0.3 %, the involvement of those buses in fatal crashes lies at 16.1 %. For motorcycles the corresponding numbers are 2.4 % and 6.8 %, for pedestrians they are 2.6 % and 4.8 %. For all other road user types the crash involvement in general is approximately equal to the fatal crash involvement.

The same authors report crash causes as stated in official police records. For the years 1993 to 1997 the police reported reckless driving to account for more than 50 % of all registered crashes. “Vehicle defects” received the next highest score and lay at about 15-20 %. As further crash causes “speed”, “external factors”, “alcohol”, “motorcyclists”, “cyclists” and “pedestrians” are reported, making the crash causes a mix of road users themselves and other factors.

Other Studies. Rwebangira et al. (1999) conducted a questionnaire survey with 200 randomly selected passengers and drivers of long distance buses and small city buses (daladalas). The crash causes that were cited most often in this study were reckless driving, speeding and driving errors. It turned out that at times passengers even encourage the bus drivers to speed up. Drugs and alcohol were also mentioned as crash causing factors. The crash causing factors of external nature that were mentioned often were poor road conditions, poor road engineering and alignment, and a lack of road signs and markings. Vehicle defects were another factor that was cited frequently as crash causing.

Another questionnaire study was conducted by Åström, Moshiro, Hemed, Heuch and Kvåle (2006). One goal was to assess the accuracy of perceived vulnerability for road traffic injury. Perceived crash causes and solutions were also investigated. The number of respondents lay at 449. The interviewees considered it to be likely to be involved in road crashes, there was even a tendency to overestimate one’s risk. Driver recklessness was
mentioned as the leading factor for crash causation, followed by drunkenness, bad road state, vehicle characteristics and a failure to enforce laws. In urban areas pedestrian carelessness ranked as high as drunkenness and bad road state. When asked about mitigating factors, almost 40% of the 818 obtained responses indicated that the drivers should be educated. Almost 30% of the urban responses demanded pedestrian education. Further responses were to improve the road state (ca. 18%), to enforce the laws, to improve the safety of the vehicles, or to monitor speed.

**Road Network.** The road network in Tanzania in 2004 consisted of about 80 000 km of roads, with the size of the country lying at 884 000 square kilometres. This means that there are about 96 km of road per 1000 km², which is a low coverage. Per 1000 inhabitants there are 2.4 km of road (Thum, 2004). It is reported that in 2004 only 44% of the road network was in good or fair condition. In 1999 about 3300 km of the trunk road network was paved (Rwebangira, et al., 1999). It is estimated that at least 60% of the smaller roads, the so-called district and feeder roads, are impassable during the rainy season, mainly due to the lack of bridges and culverts (Thum, 2004). Tanroads, the Tanzanian National Roads Agency, claims, however, that the state of the roads was improved considerably between 2000 and 2006 (www.tanroads.org).

In comparison, the Swedish road network consists of 138 000 km of public roads, 75 000 km of private roads receiving state subsidies, and many more kilometres of private roads without subsidies (Swedish National Road Administration (SNRA), 2009). The size of the country is 411 000 km². Germany, a densely populated country 357 000 square kilometres in size, has a road network of 231 000 km length, with an additional 396 000 km in municipal areas (Wikipedia – “Strassennetz”). The road density factor, excluding the municipal areas, is 650 km/1000 km², which is almost seven times as dense as in Tanzania.

**Traffic Volume.** Traffic volumes in Tanzania are low, with 200 to 500 vehicles daily on paved trunk roads in 1999, while unpaved roads saw 100 to 200 vehicles daily (Thum, 2004). Other roads were normally frequented by less than 50 vehicles per day. Traffic is growing fast, however, with an annual rate of 6-7%, and higher in Dar es Salaam. On a trunk road by far the most vehicles to be seen are trucks (around 45%), followed by pickups and 4x4-driven vehicles (36%), buses (18%) and only a small number of cars (4%).

As indicated above, the traffic safety situation in Tanzania is bad, and due to the increasing motorisation worse can be expected in the near future. Polls have been made with bus drivers and passengers (Rwebangira, et al., 1999), and with people who usually use the road as pedestrians (Åström, et al., 2006). As trucks constitute a major share of the vehicles on Tanzania’s roads, it was decided to investigate the opinion of truck drivers on traffic safety in Tanzania. Before effective measures can be deployed it is important to gain an understanding of the situation. Most likely the results obtained in Europe and other industrialised countries cannot be applied directly to a country like Tanzania, which has completely different preconditions. This questionnaire study is meant to fill part of the knowledge gap. It is hoped that the results of this study will lead to measures that will ultimately improve the traffic situation in the country.

2 **METHOD**

A questionnaire containing 24 questions, partly with sub-questions, on traffic safety as experienced by Tanzanian truck drivers was developed. Demographic data like gender and age were collected, and basic information about the truck driven was asked. Further questions concerned the truck and its quality, the driver’s own behaviour, the driver’s crash involvement, the driver’s opinion about other drivers’ behaviour and the driver’s view on how certain factors influenced crash risk.
Most questions required either a number as answer, or offered a set of alternative choices. Additionally, some open-ended questions were asked to cover aspects that might be missed by giving pre-determined alternatives.

The questionnaire was translated to Swahili, one of the two official languages in Tanzania. Swahili is spoken by a large percentage of the inhabitants. The questionnaire was printed 260 times and sent by mail to the leader of the investigation in the Mtwara region in southern Tanzania. The same number of yellow safety vests was included, which were to be given to the truck drivers as reward for answering the questionnaire.

Detailed written instructions, translated to Swahili, were sent along with the questionnaires. Five interviewers went to three different towns, which represent three major traffic centres in the Mtwara region. Two people conducted the interviews in Masasi, two in Mnazimmoja, and one remained in Mtwara. Masasi lies at the end of the paved road about 160 km from the coast, Mnazimmoja lies at the junction where the road to Masasi leaves the coastal road between Mtwara and Dar es Salaam, and Mtwara is the capital of the Mtwara region.

Each interviewer interrogated 50 truck drivers. The interviews were conducted within one week in the end of February 2009. In March the interviewers met with the researcher from VTI and gave a detailed verbal account of their experiences during the study.

3 RESULTS

The number of drivers who refused to take part in the questionnaire study is unknown, but the interviewers reported that they were not many. Therefore it is assumed that the interviewees are representative for the driver population passing through the region.

The results from the questionnaire are described broken down in sub-categories. For this paper the main focus lies on person related factors. For those questions where no missing value number is mentioned, the number lay below 10 out of 251 drivers.

3.1 Descriptives

**Nationality, age and gender.** All 251 drivers who answered the questions were Tanzanians. For 42 drivers their gender was not coded, of the remaining 209 drivers four were females and 205 were males. Their mean age was 36.4 years (std = 9.3 years), the youngest driver was 20 years and the oldest driver 70 years old.

**Work experience and age of licence.** The self reported experience of truck driving was on average 11.7 years (std = 8.7 years). The minimum experience was under a year, while the maximum driving experience lay at 47 years. The drivers had held their driver’s licences for 11.8 years on average (std = 8.6), with a minimum duration of less than a year and a maximum duration of 49 years. The correlation between years of driver’s license possession and years of experience with a truck lay at $r = .91$.

**Route related.** Most drivers had only driven within Tanzania during the last year, but a number of drivers had also driven in other African countries, most of those are either neighbouring Tanzania. In total 43 of the interviewed drivers had driven in altogether seven other countries, namely Burundi (3), Kenya (12), Congo (1), Malawi (2), Mozambique (8), Uganda (11) and Zambia (6). Even though the drivers were asked about the mileage that they had driven within the last years in the two countries that they had frequented the most, the answers indicate that a large number of drivers had difficulties estimating the distance or understanding the question correctly, therefore the results are not reported, as they probably are misleading.

3.2 Safety Related
The Vehicle. The year of manufacture was reported by 102 drivers, many of the drivers who did not report the age and weight of the truck stated that they did not have the vehicle registration card with them, and they did not know without checking the card. The mean age of the trucks for which the year of manufacture was reported was 22.4 years (std = 8.9 years). The newest truck driven in the study was one year old, while the oldest was 47 years. Most (91) trucks were between 10 and 35 years old, and the distribution over these ages was quite even. Slightly more (57 %) of the trucks whose drivers answered this question in the questionnaire are more than 20 years old.

For comparison, heavy trucks in Sweden are ten years on average, and light trucks are eight years on average in 2008. The very heavy trucks with a weight of more than 26 000 tons are the newest with an average age of five years (SIKA Institute, 2009). Generally, a truck owned by a company is younger on average than a truck owned by a person.

Driving Time. The mean reported driving time without breaks lay at 10.6 hours (std = 4.2 hours). The range is big, with one driver claiming that he takes breaks every other hour, while several drivers reported to drive for 24 hours without rest (Figure 3). The recommended driving time per day is eight hours in Tanzania, but there is no law for either driving time or compulsory breaks.

Other Drivers. It can be conclusive to ask people how they think other people behave in a certain situation, especially if the behaviour in question is not socially desirable. In the present case the drivers answered how often they thought their fellow drivers were engaged in certain activities on a scale from “almost always” over “very often”, “often” and “sometimes” to “almost never”.

The question how often other drivers would drive their truck when they were sick was answered by 230 drivers, that is, 91.6 % of all drivers. More than 50 % of the drivers assumed that this happened “almost never”, 27.8 % thought this happened sometimes, while around 14 % indicated that this happened often or more.

The number of drivers that responded to the question how often truckers drive when they are tired lay at 246, which corresponds to 98 % of the interviewees. One third claimed that other truckers drove almost never when they were tired, another third said “sometimes”. The remaining third was split between “often” (17.1 %) and “almost always” (12.2 %), while 4.5 % of the drivers said this happened “very often”.

The next question was how often other drivers were inattentive while driving. It was answered by 217 interviewees and, thus, by 86.5 % of all drivers. About two thirds thought that inattention was generally not an issue – 41.1 % of the drivers answered that this occurred “almost never”, and 25.8 % said it occurred “sometimes”. Almost 20 % of the drivers assumed that inattention occurred “often” amongst their fellow drivers, while the remaining 14 % lay at “very often” or “almost always”.

The question how often other drivers drove drunk was answered by 237 interviewees (94.4 %). Of those, one quarter claimed that their fellow drivers were almost never drunk while behind the wheel, and one third responded that they were “sometimes” drunk. Almost 20 % of the drivers thought that other drivers were drunk “often”, 8.9 % said they were drunk “very often”, and 14.3 % stated that their fellow drivers were almost always drunk while driving.

About one quarter of the 234 answering drivers reported that their fellow drivers would "almost never" drive without seat belt. Another quarter was assumed to drive sometimes without seat belt. The remaining 50 % were distributed across “often” (20.9 %), “very often” (10.3 %) and “almost always” (17.9 %).

Almost a third (29.5 %) of the drivers said that using a cell phone on the road would occur almost never, while another 25.4 % assumed that drivers would sometimes use their phones. The other drivers (54.1 %) estimated phone use to occur often (20.5 %), very often (14.8 %) or almost all the time (9.8 %). For this question the drivers are quite evenly distributed across
the answer categories. It was not asked, however, whether the driver owned a phone himself, which could have been related to the estimated phone use of other drivers.

More than four out of ten drivers (41.9%) assumed that other drivers would almost never drive too fast. Another 24.1% assumed that this would happen sometimes. The remaining third of the drivers answered that other drivers drove too fast often (12.9%), very often (5.4%) or almost always (15.8%).

More than half of the 239 drivers who answered the question reported that other drivers would almost never overload their vehicles (55.6%). Almost a fifth of the drivers thought that this occurred sometimes, while 13% assumed this to occur almost all the time. The remaining 11.7% were distributed across “often” and “very often”.

**Crash Involvement.** Crash involvement was another issue that was investigated in the questionnaire. The drivers were asked how often they had been involved in crashes so far, and whether the crash had resulted in fatalities, severely injured or slightly injured people. Of the 248 drivers (98.8%) who had answered the question, 96 (38.7%) reported that they had been involved in at least one crash. About half of those 96 drivers did not report the actual number of crashes, but only that they had been involved in at least one crash. Of the remaining drivers, 29 said that they had experienced one crash, 19 had experienced two crashes, three had experienced three crashes, two had been involved in four crashes, while five and six crashes were experienced by one driver each.

Those drivers who reported to have experienced a crash were asked about the severity of the injuries of the people involved. Just as before, most people did not indicate how many of the experienced crashes resulted in which level, and how many people in a crash had received the respective injury level. However, out of the 96 drivers with one or more crashes, 43 had experienced fatal crashes. That corresponds to 45 per cent of the reported crashes. Of the 96 drivers, 26 reported to have been in crashes with serious injuries, and 59 reported crashes with slight injuries. The numbers do not add up to 96, because drivers could report multiple injury types.

**Crash Risk.** The drivers were asked to name three common causes for crashes. In total the 251 drivers came up with 682 answers. Nine drivers did not answer the question, the others gave between one and five causes, the average number of answers lay at 2.7 per driver. The answers were coded into the categories “driver”, “other road users”, “bosses”, “police”, “vehicle”, “road” and “other”.

More than 80 drivers stated that driver recklessness was a major reason for crashes, followed by driving under the influence of alcohol, lacking attentiveness, sleepiness and speeding, which were all named by at least 15% of the drivers. Using a cell phone was only mentioned by a few drivers. Not observing the traffic code was seen as a causal factor for road crashes by a number of drivers, while some others attributed crashes to bad luck.

Of the 27 times other road users were seen as contributing factors to crashes, most blame was put on bus drivers, who race each other, and on pedestrians. All other driver types were only named once or twice. The bosses were blamed 13 times for causing crashes by being thoughtless and careless towards the drivers, by not respecting them and by paying them a too low salary. Eleven drivers named the police as crash causing, because they would accept bribes and would not do their job in an attentive manner.

Problems with the vehicle were seen as a crash cause by many drivers. More than 60 drivers reported problems with the car as leading up to crashes, and when the respondents went into detail they most often blamed the quality of the tyres. Furthermore it was stated that lacking vehicle service lay behind crashes, as did problems with the brake, low quality spare parts in general, a too heavy load of the truck and problems with the headlights.

Almost half of all respondents blamed the low standard and maintenance of the roads for causing crashes. It was also noted that road signs were lacking. Some drivers specified that
the mud or gravel surface, the narrowness of the roads and speed bumps were seen as contributing factors to crashes.

**Crash Avoidance/Mitigation.** After having been asked about the causes for crashes, the drivers were asked what could be done to avoid crashes. Again, the answers were categorised along the same categories as before, except that the category “law” was added. Just like many driver related aspects were seen as causing crashes, in many cases it was assumed that driver related mitigation strategies could avoid crashes. This was followed by road related factors. Mitigation strategies related to the vehicles were also identified 101 times, while the police, the law, the vehicle owners and other road users were only mentioned by a smaller number of drivers.

Almost 40% of the respondents indicated that they thought that driver education would help avoiding crashes. Individual actions which were singled out by a substantial number of drivers were that drivers should be more attentive, that they should observe the traffic code, and that they should not drive under the influence of alcohol. The remaining driver related strategies to avoid crashes were only mentioned by a small number of drivers each.

Other road users were not mentioned much when it comes to crash avoidance strategies, but also here education was the prominent measure to avoid crashes.

The drivers’ bosses were seen as being able to do something to avoid crashes. The general attitude of the drivers was that the bosses should be more concerned about the drivers and pay them better, six drivers suggested education for the bosses.

A number of strategies were mentioned that should be implemented at a political level. The main driver demand was that the maximum driving hours per day should be regulated by law, and that the existing laws should be enforced. In general the drivers wanted the government to be stronger on the enforcement.

Some of the drivers’ answers how to avoid crashes were directly related to the police force. Most importantly the policemen should not accept bribes, and they should adhere to the rules.

With respect to the vehicle, it was in very high demand that the trucks be serviced and repaired regularly. The spares should be of high quality, and again, special focus was put on the tyres. It was also mentioned that the vehicle should be checked before each journey.

Almost half of the drivers assumed that crashes could be avoided if the roads would be repaired and well maintained. Some drivers mentioned explicitly that the roads should get paved. Another aspect that was important to the drivers was that more road signs should be put up.

### 4 DISCUSSION

Just as in Europe the truck drivers were predominantly male. The age span was large, but most drivers were in their 20s and 30s. Only few drivers were older than 60. Generally a higher age also means more driving experience, and most drivers had driven trucks more or less as long as they had held the driver’s licence for trucks.

In contrast to European countries, where truck drivers often cross borders and drive in other countries than their own, all interviewees in the present study were of Tanzanian citizenship, and most of them stemmed from the south, the area in which the interviews were being conducted. This leads to the assumption that the drivers are quite familiar with the roads they drive on, and with the general conditions in the area. Most drivers also reported that they mainly drove in Tanzania, even though the travelled distance could not be estimated conclusively, due to misunderstandings when asking the question. Some neighbouring countries were visited by a few drivers, but for the drivers interviewed cross-border traffic is rather unusual.

#### 4.1 Safety Related
Around 40% of all drivers interviewed had already been involved in at least one crash, and half of those drivers had been involved in fatal crashes. Fatalities are likely to occur in crashes with trucks, because very often the other involved partner is an unprotected road user, or it is a single accident where the victims are passengers travelling on the cargo area in the back of the truck. Severe injuries were also likely, and considering the state of the health care system severe injuries are likely to lead to death or lifelong damages for the victim.

The high crash involvement rates of the truckers indicate once more that even though the fatality and crash risk for the population is still low, the fatality rate counted per vehicle is very high. Of 248 truck drivers, which is equalled with 248 trucks, 43 have seen at least one fatal crash. If the numbers obtained in the interviews here are representative for the country, the fatality rate per 10,000 trucks would lie at least at 1733! For this computation it was assumed that the 43 trucks were involved in only one fatal crash with only one person dead, which is an underestimation of reality. The fatality rate per vehicle in Tanzania was reported to be 111 (see above), which would imply that trucks are more than 15 times as deadly as the average vehicle. Therefore, truck safety should be of paramount concern when dealing with traffic safety in the country.

It is notable that about a third of the trucks is not equipped with seat belts. Those drivers who have seat belts are, however, very likely to use them. It is known that seat belts are very effective in reducing the fatality risk (Evans, 1988), and a wider spread of seat belts in trucks and cars, both for drivers and passengers, would surely contribute to a reduction in fatalities.

Tanzanian truck drivers drive for a very long time on average without rest. The interviewers reported also that the inhumane driving hours imposed by the drivers’ bosses were of major concern to the drivers themselves. Driving for so long leads to fatigued, tired and inattentive drivers, which are more likely to end up in hazardous situations or crashes. Some drivers even reported to drive for 24 hours without rest, which is four times more than the recommended driving time per day. The situation is aggravated by the fact that there is no simple means of controlling a driver’s time at the wheel. Tachographs are not being used, and there is a general lack of central registration of traffic offences. Tackling the problem of extended driving hours is paramount, however, if the traffic safety is to be increased.

More than one third of the drivers reported that it happened often, very often or almost always that drivers drove when tired. Another third said this happened sometimes. This is quite understandable when looking at the trip duration without rest reported by the drivers in this study. The percentage of fatal crashes related to sleepiness in Europe and the USA has been estimated to lie between 10 and 30% or even higher (Åkerstedt, 2000; Åkerstedt, Connor, Gray, & Kecklund, 2008). Sleepiness based crashes have a tendency to have more severe outcomes than average, because they often occur at relatively high speeds (Zulley, Crönlein, Hell, & Langwieder, 1994). The prevalence of sleepiness in Tanzanian truck drivers is extraordinarily high, and around 20% of the drivers name sleepiness as one major cause for road crashes. The drivers are also aware of the fact that being sleepy and that driving long distances without rest increases the crash risk.

It is likely that a substantial number of the more severe crashes are due to sleepiness. Often truck drivers drive at night when on asphalt roads, because then the asphalt is less warm and therefore harder, making driving easier. However, driving at night will increase sleep deprivation, and is also dangerous for other reasons.

When asked about measures for crash prevention, sleepiness related issues were not addressed as directly and as often. That drivers should take a break when tired was only mentioned five times, and one driver demanded education on how to get rid of sleepiness. Almost 40% of the drivers asked for education, however, and six drivers mentioned specifically that the bosses should be educated. Law enforcements were also mentioned, but without specifically naming sleepiness problems. It might be possible that the drivers do not
believe that something can be done about the sleepiness problem, or they hope that general education will help them get rid of it. Another interpretation might be that other issues are more important to them, like the state of the road and the vehicle, and therefore sleepiness related countermeasures were not named among the three most important countermeasures.

Illness was not much mentioned as a crash causing factor. The drivers in this study reported, however, that it was relatively common for drivers to be on the road while sick. More than 40% assumed that this happened at least sometimes. In general the drivers were aware of the fact that driving while sick increases the crash risk, but the percentage of drivers who are not aware of this fact was not neglectable. Information on the consequences of driving when not fully capable of concentrating on the road due to illness might be able to help preventing some drivers from driving while ill.

It can be assumed that most drivers are ready to drive when sick, because they are afraid of losing their jobs. It is dangerous that drivers do not appear to grasp the full implication of the danger of driving while being sick. Here it is probably necessary to address the employers as well, because they often dictate harsh working conditions for the drivers as there are many unemployed people desperate for a job. For the employer not only the live and health of his drivers is at stake, but in case of a crash caused by a sick driver he will also suffer economic loss.

Speeding appears to be common on all road types. The drivers are aware of the risk of driving too fast as one fifth of the drivers mentioned speeding as a leading crash cause. Nevertheless a large amount of drivers appears to speed.

The single most named crash cause is driver recklessness. “Not observing the traffic code” can also be subsumed under recklessness. The most mentioned driver related countermeasure was education, which, together with enforcement, should be addressed at recklessness. Recklessness often means driving at high and inappropriate speeds, but also risky overtaking manoeuvres and other careless behaviour. A personal communication with the Chief Engineer of the Ministry of Infrastructure in Tanzania revealed that the truck driver education only comprises of teaching how to drive the vehicle, but there is no education about traffic rules and traffic safety related issues. It can therefore be assumed that drivers do not necessarily act out of ill will, but that they sometimes just do not know any better. Furthermore, since the vehicle density in Tanzania is so low, “traffic sense” is not necessarily instilled during childhood and while growing up, because many drivers probably get into a vehicle on a regular basis first after they have got their driver’s licence.

About a quarter of the drivers assume that other drivers are distracted often while driving. Almost 20% also name a lack of attention as a major crash cause.

The lack of attention could be subsumed under recklessness, but is of a slightly different quality. While recklessness comprises more active “bad behaviour”, lacking attention is not necessarily seen as risky by the driver. A driver might talk on the phone, talk with a passenger, or be distracted due to other causes. In the US and European countries distraction is assumed to lie behind a large percentage of crashes (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Klauer, Sudweeks, Hickman, & Neale, 2006; Stutts, et al., 2003; Stutts, Reinfurt, Staplin, & Rodgman, 2001). The types of distraction are, however, most likely very different in industrial countries where vehicles typically are equipped with info- and entertainment systems, and where traffic looks completely different than in Sub-Saharan Africa. In order to estimate the percentage of crashes due to distraction in Tanzania the prevalence of distraction both during normal driving and for crashes would need to be established, as data from industrialised countries cannot be taken as reference.

Talking to passengers and on the cell phone is seen as crash risk increasing by a number of drivers, but just as many think that crash risk will be reduced. A possible interpretation might be that the drivers think a conversation will keep them from falling asleep.
passengers have actually been found to have a slight crash risk reducing effect (Dingus, et al., 2006), because they can point out things to the driver that the driver missed. Talking on a cell phone, however, is generally seen as detrimental to traffic safety (Kircher, et al., 2004). To the knowledge of the author, there are no studies that investigate the role of a mobile phone as sleep preventing, which could be of interest for future studies.

Of the driver related factors, drunkenness is the second most mentioned crash cause. Also, the drivers assume that being drunken increases the crash risk substantially, and ceasing to drink while driving is mentioned as a crash reducing measure by 30 of the 250 drivers. Drunkenness is therefore an issue that many drivers are aware of, and that was mentioned as a measure to fight sleepiness. As sleepiness and drunkenness interact and increase crash risk vehemently (Åkerstedt, et al., 2008), a reduction of both would probably have a large impact on traffic safety. Here again, as with speed, we encounter the problem that drivers are aware of the risks with alcohol, but they drink nevertheless. Therefore, pure driver education is not enough, a structural change involving politicians, legal instances, enforcement and possibly a campaign to address the public opinion are necessary.

4.2 Vehicle Related Problems
The vehicles in use are rather old on average, more than twice as old as the average truck in Sweden. An old vehicle fleet entails a number of problems, one of which is a lack in safety equipment. Older trucks are less likely to have seat belts, for example, which unnecessarily endangers the drivers’ lives. Even though seat belts are an effective and relatively cheap method to save at least the driver’s life, they are unlikely to be retro-fitted in old trucks. Also, older trucks are more likely to break down, which is easily understandable. It might seem paradoxical that in spite of this older trucks are serviced or repaired more rarely in official garages. It is possible, however, that vehicle owners who have old trucks are more likely to save money, thus, they own older vehicles, and they do not grant them a more expensive service or repair in an authorised garage. They either turn to the cheaper local workshops that are often less competent and well equipped for repair and maintenance work or they make the necessary repairs themselves and skip those that are not necessary to keep the truck running. Hence, these older trucks are a traffic hazard both to their own drivers and passengers and other people on the road, because vital parts are more likely to fail than on newer trucks.

4.3 Road Related Problems
Drivers mentioned the bad state of the roads very often. Some drivers wanted more roads to be paved, but the general demand was that the roads be maintained better. Another issue that was important to drivers were the road signs. A lack of signs was seen as causing crashes, and an installation of signs was suggested frequently as a crash avoiding factor. Exactly which type of signs should be installed was not mentioned, but it is likely that drivers are interested in warning signs that draw their attention to particular hazards. To illustrate this, in one instance of a crash, for example, the bridge across a river had been washed away by a flood years ago. The sign indicating that had been stolen, and a new bus driver on the road received no warning for the lacking bridge when driving fast along the asphalt covered road in darkness. He drove into the hole and the river below at full speed, killing all his passengers and himself. This type of crash is not unusual, and driving at night oftentimes means to drive in complete darkness, except for the often not very well operating vehicle headlights. Here, warning signs could really improve the perception of unexpected hazards. This would also mean, however, that the signs need to be guarded, as theft is not uncommon, with metal being a valuable material.

Especially during the rainy season the roads in southern Tanzania are notoriously bad. At times even the main roads become impassable or very difficult to navigate due to mud,
slippery soil and flooding. Therefore it is important for drivers to collect fresh information about the state of the road before heading out for a longer trip. It is important that those drivers who are in need of information about the state of the road should be able to get it, because this could prevent a number of crashes, but also keep drivers from getting stuck on the road, which can lead to other hazards like robbery, being bitten by mosquitoes transmitting malaria, or other illnesses.

4.4 Other Issues
Even though the bosses were not often directly named as causing crashes, they appeared somewhat more frequently when talking about crash avoidance strategies. The drivers were of the opinion that the bosses do not listen to them, and that they put them under a lot of pressure without paying them appropriately. Furthermore, it is the bosses’ responsibility to ensure that the vehicle is in good working order. Some drivers suggested that the bosses be educated, which should clearly be considered when developing an integrated traffic safety concept. The police received some criticism from the drivers. It was mentioned that policemen accepted bribes instead of collecting fines for offences, and therefore the traffic safety would not be increased.

The police was also mentioned in connection with crash avoidance measures. Specifically, policemen should not accept bribes and adhere to the rules. It has to be mentioned, however, that even if the police did their job completely accurately, they would confront a number of obstacles. There is no central register for traffic offences, therefore repeat offenders are not punished more than first time offenders, for example. As indicated above, it is not either possible to control the working hours of the truck drivers, there is not even a legal limit for how long the drivers are allowed to drive. Here, not only the police has to improve its quality of service, but also the legislation has to be improved to protect the truck drivers, and by that the other road users as well.

5 CONCLUSIONS
Now is the time when actions should be taken to reduce the fatality rate, not only because the fatality risk will increase dramatically with an increasing motorisation, but also because now only a small percentage of the population is in possession of a driver’s licence. It should still be possible to reach most of those drivers with further educational measures, and it is of necessity to educate new learner drivers about traffic safety. Furthermore, education of the drivers’ bosses, of the enforcement organs and other road users is important, but the state of the vehicles and the roads should not be neglected, either.

The research done contributed with new information about a group of drivers that had not been investigated before in this manner. It is hoped that this will spur further projects, which will actually take action to improve the situation for all road users in Tanzania.

REFERENCES


ASSESSMENT OF ROAD USER BEHAVIORAL ASPECTS OF RELEVANCE TO TRAFFIC SAFETY IN UAE

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ABSTRACT
This paper discusses the behavioral issues of road users, and their effect on traffic safety in the UAE. It describes the process of a road user survey design, data collection, sampling, data coding, and analysis of the results using descriptive statistical analysis. The survey is designed to identify the road users behavior, and to collect public opinions regarding road users’ behaviors and implications on traffic safety. The road user survey includes questions related to the causes of violations and/or accidents that road users had been involved in. The survey was distributed over the entire country (across all the emirates), and then data analyses were conducted. The paper also addresses issues of relevance to recent police accident reports.

A list of recommendations is presented such as improving the role of media, and providing safety courses for new drivers. Other recommendations include providing elementary traffic safety courses to school students, and using new technologies to control and eliminate unsafe behavior of drivers.

1 INTRODUCTION
Road accidents are considered the major cause of deaths and injuries in the UAE. These accidents represent a burden on future plans for social and economic developments of the country. The problem becomes clear with the increasing and growing numbers of traffic accidents. The increasing number of road users and the corresponding increase of traffic accidents and violations of traffic laws, imposes great challenges on the relevant key...
stakeholders including the police, the Department of Transport, Roads and Transport Authority, and the traffic departments in the municipalities.

Tasca (2000) considered the driving behaviour to be aggressive if it is likely to increase the risk of collision, and if it is motivated by impatience, annoyance, hostility and/or an attempt to save time. However, not every moving violation is considered aggressive driving. Multiple violations such as speeding, following too closely, making unsafe lane changes and running red lights, either on one occasion or over a period of time, may indicate a pattern of aggressive driving (NHTSA, 2008a).

The negative behaviors of drivers could vary in type and distribution from one country to another. Kontogiannis et al. (2002) reported that exceeding the speed limit and not using seat belts were the most common negative behaviors of drivers in Greece, represented by 50% of the drivers. Meanwhile, results of a study questionnaire about aggressive driving (King and Parker, 2008), showed how people partly justify their driving violations according to the behavior of other drivers. In another study, it was proved that the most important reasons for reckless driving in Saudi Arabia is young drivers, and driving at an early age. Al-Hammadi (2008), for example, reported that 47% of young Saudi people who drive cars have learned driving in the age between 14 and 17 years. The author also explained that the main causes of accidents in Saudi Arabia are speeding on the road and sudden deviation from the driver’s lane. According to the NHTSA (2007a) data, speeding was a factor in 30% of the fatal crashes that occurred on dry roads in 2007, and the cost of speeding-related crashes was estimated to be $40.4 billion in 2000. From NHTSA (2008b) data, it was also estimated that alcohol was involved in 41% of fatal crashes and in 9% of all crashes in 2006. Besides, and according to the National Occupant Protection Use Survey as cited by NHTSA (2007b), 5% of drivers in 2006 used hand-held cell phone while driving, and 83% used seat belts in 2008. (NHTSA, 2008c). NHTSA (2007c) summarized the related factors for drivers and motorcycle operators involved in fatal crashes in 2005 as follows: (1) failure to keep in proper lane or running off road, (2) driving in excess of posted speed limit or racing, (3) driving under the influence of alcohol, drugs, or medication, (4) failure to yield right-of-way, (5) inattentive (talking, eating, etc.), (6) reckless, (7) careless or negligent operating manner, and (8) others.

Several investigators studied the causes of drivers’ negative behaviors. Tasca (2000) listed the main factors which seem to increase aggressive driving behavior as follows; being relatively young, being male, being in an angry mood, believe that one possesses superior driving skills, and traffic congestion (but only if drivers do not expect it). Also, Leon and Diane (2000) listed other reasons behind aggressive driving like; being under the influence of alcohol, drugs, medication, drowsiness, depression, severe pain, anger or rage, fear or panic, stress, speed and risk addiction, driving distracted, lack of awareness, and habitual denial of one's own driving mistakes. Kontogiannis (2006) indicated that higher stress was associated with higher levels of errors and violations.

The main reason for most accidents in various parts of the world occurs due to human errors. According to the accident reports of 2007, 63% of the total accidents that occurred in the UAE were due to human factors (UAE MOI, 2007), while 2% were caused because of vehicle defect, and 35% happened because of other reasons. Figure 1 presents the distribution of the most important and common behaviors that caused traffic accidents in the UAE in 2008. Obviously, there are several negative attitudes of road users in the country. Such behaviors, as well as other factors, were the reasons of a total of 10135 accidents in that year (UAE MOI, 2008).
The negative behavior of road users does not only affect traffic safety, but also affects the efficiency of traffic flow. For example, negative behaviors could result in an increase of travel time due to traffic obstruction. According to the Annual Statistics Traffic Report (UAE MOI, 2007), the total number of traffic violations in 2007 were 4,629,564.

Stutts et al. (2005) listed different strategies for reducing collision due to driver inattention as follows; focusing on increasing driver awareness of the risks of drowsy and distracted driving and promoting driver focus by conducting education and awareness campaigns targeting the general driving public, and visibly enforce existing statutes to deter distracted and drowsy driving. Rashad (2001) suggested different solutions for the enhancement of traffic safety such as; establishing a traffic school for children that teaches traffic rules and road ethics, establishing a training field to teach children the rules and etiquette of traffic, enhancing traffic culture in schools by teaching traffic courses for all students, which should be taught by the traffic police, and to include special films about traffic and its objectives.

Work related to the types and reasons of negative behavior of drivers in the UAE is greatly lacking. Thus, one of the objectives of this study was to classify road users and identify the types of negative behaviors associated with driving in the UAE. Another objective was to understand the causes behind negative behaviors of road users and to identify any relationship between negative attitudes of road user and traffic violations. To achieve these objectives, data from the Annual Statistical Reports of the UAE were utilized along with a survey that was distributed among road users.

2 METHODOLOGY
The methodology used in this study includes an extensive, in-depth review of previous relevant studies and distribution of a questionnaire among road users in the different emirates of the country. More details of the tools of the study are described below.

2.1 Police Reports
Traffic incident records for the past four years (2005 to 2008) were extracted from the UAE police reports. These reports include all traffic incidents in the country as a whole, and those
specific to each emirate. Data from these reports (including violations and traffic accidents) were analyzed to determine the causes of accidents and to identify the most common traffic violations. Furthermore, available data from the reports were utilized to determine the changes in the number of accidents and violations over the last four years, according to traffic rules in the UAE.

2.2 Road User Survey

Based on previous studies and a thorough review of the UAE police reports, a road user questionnaire was initially designed using the stated preference survey method. In this method, a number of questions with pre-defined options were used. In other words, choosing the most appropriate answer from several answers. In addition, the survey included some open ended questions, where people can add more answers or points regarding a particular question.

The prepared questionnaire consists of 51 questions, of which 46 are single variable questions and 5 are multiple variable ones. The sample size of the distributed questionnaire was specified using the method of adding successive groups of respondents, as well as studying the change of the most varying variables in the survey. At the beginning, 50 responses were collected and utilized to estimate the standard deviations of all variables. In the second step, another 50 responses were utilized along with the previous ones (for each emirate), to determine new values of standard deviations for all variables. In the third step, the difference of the variable variance between two consecutive steps was calculated. The number of samples at which the difference of the variable variance stabilizes is considered to be the minimum sample size for each emirate. The total number of collected samples was 1662 surveys for the whole UAE. Table 1 shows the mean and the standard deviation for some survey questions’, for the responses obtained from Abu Dhabi city. Similar analysis were carried out for the other emirates.

Table 1: Variations of the mean and standard deviation values for Abu Dhabi samples.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean / STDV</th>
<th>50 samples</th>
<th>100 samples</th>
<th>Difference</th>
<th>Difference</th>
<th>Difference</th>
<th>Difference</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>How often do you use your mobile phone while driving?</td>
<td>Mean 2.75</td>
<td>2.53</td>
<td>-0.22</td>
<td>2.59</td>
<td>0.06</td>
<td>2.78</td>
<td>0.19</td>
<td>2.71</td>
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<tr>
<td></td>
<td>STDV 1.256</td>
<td>1.272</td>
<td>0.016</td>
<td>1.199</td>
<td>-0.073</td>
<td>1.165</td>
<td>-0.034</td>
<td>1.118</td>
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<tr>
<td>How often do you drive without leaving sufficient distance with front vehicle?</td>
<td>Mean 2.93</td>
<td>2.98</td>
<td>0.05</td>
<td>3.02</td>
<td>0.04</td>
<td>3.18</td>
<td>0.16</td>
<td>3.13</td>
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<tr>
<td></td>
<td>STDV 1.047</td>
<td>1.018</td>
<td>-0.029</td>
<td>0.996</td>
<td>-0.022</td>
<td>0.966</td>
<td>-0.030</td>
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<td>How often do you drive without renewal/ owning driving license?</td>
<td>Mean 3.78</td>
<td>3.76</td>
<td>-0.02</td>
<td>3.73</td>
<td>-0.03</td>
<td>3.77</td>
<td>0.04</td>
<td>3.75</td>
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<td></td>
<td>STDV 0.530</td>
<td>0.579</td>
<td>0.049</td>
<td>0.632</td>
<td>0.053</td>
<td>0.587</td>
<td>-0.045</td>
<td>0.595</td>
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<td>How often do you run the red light?</td>
<td>Mean 3.61</td>
<td>3.74</td>
<td>0.13</td>
<td>3.68</td>
<td>-0.06</td>
<td>3.75</td>
<td>0.07</td>
<td>3.75</td>
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<tr>
<td></td>
<td>STDV 0.771</td>
<td>0.623</td>
<td>-0.148</td>
<td>0.627</td>
<td>0.004</td>
<td>0.571</td>
<td>-0.056</td>
<td>0.573</td>
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<tr>
<td>How often do you drive without using seat-belt?</td>
<td>Mean 3.29</td>
<td>3.25</td>
<td>-0.04</td>
<td>3.14</td>
<td>-0.11</td>
<td>3.21</td>
<td>0.07</td>
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</tbody>
</table>
The results in Table 1 indicate that stability in response was almost achieved by a sample size of 250 for Abu Dhabi city. Nevertheless, a total sample size of 1662 was collected to account for minimum sample size statistical analysis.

3 RESULTS AND ANALYSIS
3.1 Traffic Violations
Table 2 shows the different types of traffic violations in the UAE during the years 2005-2008. The total number of traffic violations in the country for the year 2008 almost reached 4.5 million violations. Compared to a previous year, the number of traffic violations has increased by 39% in 2006 and by 13% in 2007. But, the number dropped by around 3% in 2008. This slight decrease, however, can not be used as an indicator of a further drop in traffic violations in the coming years.

Table 2: Most common violations in the UAE for the years 2005 to 2008.

<table>
<thead>
<tr>
<th>Most common traffic violation in the UAE</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceeding speed limit by radar</td>
<td>1964785</td>
<td>2470304</td>
<td>3000000</td>
<td>2378266</td>
</tr>
<tr>
<td>Not following traffic lane</td>
<td>84678</td>
<td>150068</td>
<td>193970</td>
<td>279822</td>
</tr>
<tr>
<td>Obstructing traffic</td>
<td>115622</td>
<td>178352</td>
<td>198538</td>
<td>NA</td>
</tr>
<tr>
<td>Parking in not allowed places</td>
<td>147807</td>
<td>256184</td>
<td>213983</td>
<td>NA</td>
</tr>
<tr>
<td>Not using seat belts while driving</td>
<td>41871</td>
<td>159897</td>
<td>78649</td>
<td>44732</td>
</tr>
<tr>
<td>Reckless driving</td>
<td>73446</td>
<td>171044</td>
<td>114162</td>
<td>21595</td>
</tr>
<tr>
<td>Others</td>
<td>505722</td>
<td>698831</td>
<td>830262</td>
<td>1773719</td>
</tr>
<tr>
<td>Total</td>
<td>2933931</td>
<td>4084680</td>
<td>4629564</td>
<td>4498134</td>
</tr>
</tbody>
</table>

The most common traffic violation in the UAE during the last four years was exceeding the speed limit, with about 2.4 million violations in 2008. Other types of traffic violations that are common in the country include obstruction of traffic, not following traffic lane, parking in not allowed places, not using seat belts while driving, reckless driving, and “others”. The “others” category represents all the other types of violations including many items with less frequencies of occurrence. Figure 2 illustrates the distribution of traffic violations in the UAE for the years 2005-2008.
3.2 Traffic Accidents

The UAE police reports reveal that the total number of traffic accidents was 10135 in 2008, compared with 8828 in 2007, and 8843 in 2006 (Table 3). The increase in the number of traffic accidents is approximately 15% between the years 2007 and 2008, and 4% between the years 2006 and 2007.

Table 3: Causes of accidents in the UAE during the years 2005 to 2008.

<table>
<thead>
<tr>
<th>Cause of accident</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not respecting other road users</td>
<td>2024</td>
<td>1877</td>
<td>2081</td>
<td>2314</td>
</tr>
<tr>
<td>Not following traffic lane</td>
<td>821</td>
<td>757</td>
<td>692</td>
<td>811</td>
</tr>
<tr>
<td>Entering road without making sure that it is free</td>
<td>946</td>
<td>864</td>
<td>863</td>
<td>965</td>
</tr>
<tr>
<td>Not leaving sufficient distance with front vehicle</td>
<td>910</td>
<td>732</td>
<td>769</td>
<td>1094</td>
</tr>
<tr>
<td>Running red light</td>
<td>739</td>
<td>508</td>
<td>419</td>
<td>545</td>
</tr>
<tr>
<td>Exceeding speed limit</td>
<td>695</td>
<td>482</td>
<td>533</td>
<td>369</td>
</tr>
<tr>
<td>Reckless driving</td>
<td>138</td>
<td>204</td>
<td>184</td>
<td>206</td>
</tr>
<tr>
<td>Tire explosion</td>
<td>354</td>
<td>170</td>
<td>172</td>
<td>160</td>
</tr>
<tr>
<td>Others</td>
<td>3178</td>
<td>2849</td>
<td>3115</td>
<td>3671</td>
</tr>
<tr>
<td>Total</td>
<td>9805</td>
<td>8443</td>
<td>8828</td>
<td>10135</td>
</tr>
</tbody>
</table>

The main causes of traffic accidents in the UAE were as follows; not respecting other road users, not following traffic lane, entering road without making sure it is free, not leaving enough distance with the front vehicle, running a red-light signal, exceeding speed limit, reckless driving, tire explosion, and others (i.e., road defects, weather conditions, etc.). The distribution of accidents by cause in the country during the last 4 years is presented in Figure 3. As the figure shows, more than 20% of the accidents in the UAE occurred because of not respecting other road users.

Figure 2: Distribution of traffic violations by type in the UAE during the years 2005-2008.
3.3 Analysis of the Survey Data

Using the collected data pertinent to different traffic issues as well as those collected from the road users, a statistical analysis was conducted using the Statistical Program for Social Sciences (SPSS). It should be noted that the survey data were analyzed after completing the distribution of the questionnaire over all the emirates, and checking the minimum number of samples required for the study by comparing the standard deviation for the data. Based on that, all the questions were analyzed without considerations of the location from which the questionnaire was collected. In other words, all the data were pooled to represent the UAE as a whole. Results obtained from the survey are summarized below.

As shown in Table 4, most of the respondents were between 26-40 years old, males, from Arab countries, with high level of education, having a driving experience of more than 10 years, and they travel on the average less than 100 km per day. Based on previous information of the respondents, it is clear that the respondents were the target group which represents the majority of road users.

Table 4: Percentage distribution of the road users’ personal information

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>18-25 years: 17%, 26-40 years: 47%, 41-60 years: 34%, More than 60 years: 20%</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 85%, Female: 15%</td>
</tr>
<tr>
<td>Highest level of education</td>
<td>Reading and writing: 2%, Elementary: 3%, Secondary: 15%, High school: 26%, College/ university: 54%</td>
</tr>
<tr>
<td>Nationality</td>
<td>Emirati: 26%, From a Gulf country: 4%, Arabian country: 47%, Asian country: 16%, Others: 7%</td>
</tr>
<tr>
<td>Driving experience</td>
<td>Less than 2 years: 13%, 2–5 years: 22%, 5-10 years: 24%, More than 10 years: 41%</td>
</tr>
<tr>
<td>Average daily travel distance (km)</td>
<td>Less than 60 km: 35%, 60-100 km: 35%, 100-150 km: 18%, 150-200 km: 6%, More than 200 km: 6%</td>
</tr>
</tbody>
</table>
Respondents were asked about the reasons of accidents they were involved in (if any). Their answers were in the following order: exceeding speed limits (14.7%), reckless driving (12.6%), not leaving sufficient distance with the front vehicle (12.6%), sudden deviation (7.5%), and entering a road without ensuring that it is free (6.6%). Other factors along with their distribution are presented in Figure 4.

![Figure 4: Distribution of causes of accidents which respondents had been involved in.](image)

Apart from the behavioral aspects, the results indicated that the factors of the traffic accidents which the respondents had been involved in were related to the weather conditions, followed by defects in the vehicles, then defects in the road (Figure 5).

![Figure 5: Contribution of different factors to traffic accidents in the UAE.](image)

The results of the survey further indicated that around 39% of the violations (which the respondents did) were exceeding the speed limit, followed by around 16% due to parking in not allowed places. Other violations which respondents had are shown in Figure 6.
Figure 6: Types and distribution of violations which respondents had been involved in.

As demonstrated in Figure 7, respondents indicated that the main reasons for traffic violations are: “being in a hurry”, traffic congestion, and stress or fatigue.

Figure 7: Reasons of respondents' violations.

The reported reasons behind the negative behaviors of the road users in general are: desire for speeding and risk-taking (18.1%), lack of awareness and denial of errors (17.1%), driving under the influence of stress (14.1%), anger (13.6%), excessive self-confidence (12.4%), and being under the influence of drug and/or alcohol (7.9%), as shown in Figure 8.
Figure 8: Causes and distribution of negative behaviors of other road users.

With regard to the attitude of road users (e.g. how often he/she exceeds the speed limits, park in not allowed places), Figure 9 illustrates the distribution of the responses. The most common negative behavior of drivers in the UAE is using the mobile phone while driving, followed by exceeding the speed limit. The details of the answers are shown in Figure 9.

Figure 9: General behavior of road users in the UAE.
Respondents indicated that the strict enforcement of the traffic laws is the most effective mean to limit the negative behaviors of road users. Other means included enriching the Media role and participation, and the use of new technologies as shown in Figure 10.

Figure 10: Most effective means to limit negative behaviors of road users.

4 CONCLUSION AND RECOMMENDATIONS

In this study, the most common negative behaviors of road users in the UAE was discussed based on available data of traffic violations and accidents, and data collected from a stated-preference survey. It was found that exceeding the speed limit and not respecting other road users were the most common traffic violations and main causes of accidents in UAE. Respondents believe that “being in a harry” is the main reason for their traffic violations.

In order to improve the road user behavior, several actions are suggested including:
1. Design a simulation program for road users and the surrounded environment. This will help capture the diversity of the drivers’ behaviors in a rigorous scientific way.
2. Include educational programs about traffic safety in school curricula.
3. Apply advanced technology for traffic monitoring and vehicle control.
4. Support and develop techniques for better traffic management with particular emphasis on increasing the number of police patrols in the streets.
5. Initiate a probationary period for young and new drivers.
6. Activate the role of media.
7. Support the new traffic law by using a more effective immediate short messaging system (SMS).
8. Honor outstanding drivers for their safe driving.
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REFERENCES


Posters

A preliminary Study on Characteristics and the Contributing Factors for Single Vehicle Collisions Involving Trees in Malaysia
Z.A. Ahmad Noor Syukri, Malaysian Institute of Road Safety Research, Malaysia

Status of Traffic Safety in the UAE
Mohammad Nurul Hassan, RTTSRC, Research Affairs, UAE University, United Arab Emirates

A Safety Audit Approach in Ranking Urban Road Crash Hotspots Using Analytical Hierarchy Process (AHP), (Case Study: Region 20 of Tehran)
Mohsen Fallah Zavareh, Traffic and Transportation Deputy, Municipality of Tehran, Iran

Setting up an Indicator System for Monitoring Road Safety Using the Road Safety Target Hierarchy
Gert Wets, IMOB – Hasselt University, Belgium

A Statistical Analysis of Perceptive Functional Failures – Driver Behaviour Preceding Collisions
Deniz Atalar, Ergonomics and Safety Research Institute, Loughborough University, UK

Setting Appropriate Posted Speed Limit in the Emirate of Abu Dhabi
Abdulilah Zineddin, Abu Dhabi Department of Transport, United Arab Emirates

Knowing your Speed can Save your Life
Koh Puay Ping, Land Transport Authority, Singapore

Vehicles’ Type and Engine Power as Factors Affecting Drivers’ Risk Perception of the Geometric Characteristics of Road Network
Prof. Nikolaos Eliou, University of Thessaly, Greece

Economic Appraisal and Optimization Process in Road Safety Projects
Hamid Reza Behnood, Techno-Economic Road Safety Research Center, Ferdowsi University of Mashjad, Iran

Safe of Wider Edge Lines in the USA
Paul Carlson, Texas A&M University, USA

A Simulation-Based Traffic Safety Evaluation of Signalized and Un-Signalized Intersections
Tom Brijs, Transportation Research Institute (IMOB) Hasselt University, Belgium

The Malaysian Value of Reducing Fatal and Non Fatal Injuries Due to Road Accidents: A Willingness to Pay Study Using Conjoint Analysis Approach
Prof. Hj Mohd Faudzi Mohd Yusof, Malaysian Institute of Road Safety Research, Malaysia
ABSTRACT
The aim of this study was to investigate single vehicle collisions involving trees in Malaysia by using the police national database though (Pol 27) as the data source. From the Pol 27, information on tree-related traffic collisions in year 2006 and 2007 was gathered. The accumulation of cases in both years proved fatal tree-related cases as the highest (38%) compared to non fatal tree cases. Factors which were analyzed from the Pol 27, viz., day, time, area type, road geometry, numbers of carriageway, pavement quality and road shoulder width. A Mann-Whitney U Test was performed to identify pattern variation on seven contributing factors between the two years data from Pol 27. From the comparison done, numbers of carriageway and pavement quality factors displayed significant variation between the two years information that was revealed from the Asymp. Sig. value. Cross tabulation analysis and chi-square test were also performed to determine the odds ratio value and chi-square value, respectively. From the chi-square test, only time and road shoulder width factors were found to be associated to injury severity level in tree related collisions. Odds ratio value revealed only time, number of carriageways, pavement condition and road shoulder width recorded significant values. Nighttime (time), dual carriageways roads (number of carriageway), wavy and holed condition roads (pavement quality) and roads with road shoulder width below 2.5 m (road shoulder width) were identified as the more influential variables in fatal tree related collision cases. The findings from this study highlight the crucial variables to be focused on during future interventions to cater tree related collisions.

1 INTRODUCTION
In Malaysia currently, single-vehicle collisions or run-off-road (ROR) collisions are of significant concern. Based from Malaysian Police (PDRM) data, single vehicle collision recorded 30.1% fatal cases per the total number of fatal accidents and 17.1% severe injury cases from the total number of severe accidents cases for year 2006 while 26.9% (fatal) and 16.1% (severe) for year 2007. However, up to now, single-vehicle collisions still have not been comprehensively investigated to portray the Malaysian scenario.

In a single vehicle collision, the vehicle will more likely to leave the road and have a collision within the road shoulder. The collision could be with fixed objects (poles, posts, trees, walls, bridge supports or fences) or could involve contact with an embankment, slope or ditch.

Diverse driving indiscretion, such as poor overtaking, hydroplaning and underestimating curves could result in vehicles colliding with road furniture, trees or parked vehicles. Trees are treated differently because they are the most available objects along roads and one of the most rigid. And in the Malaysian scenario, given the fact of the nature of the tropical climates
in the country, the number of trees available along road shoulders in Malaysian is undeniably abundant.

Collisions between vehicles and trees are a major type of traffic fatality. According to Naing et al. (2007), cited from the research paper prepared for ETS (Road Infrastructure Working Party (1998)), studies in Europe have shown that collisions with road shoulder objects accounted for between 18% and 31% of all fatal collisions, with trees and utility poles being reported as the most frequently struck objects (ETSC 1998).

Injury outcomes in tree crashes are typically worse than in car-to-car crashes because in tree crashes, the vehicle has to absorb all the impact energy which is applied to a relatively small area of the vehicle while in a car-to-car crash, both vehicles in the crash absorb the crash energy and the impact energy is typically distributed over a wider area (Morris et al. 1999).

Prior to the present study, according to the knowledge of the authors, there has been neither research activity nor report on the issue of single vehicle collisions involving trees in Malaysia. Thus, the present study was initiated, as the first step to determine the crucial factors associated to tree-related collisions in Malaysia.

2 METHODOLOGY
The methodology of this study is divided into four parts as shown in Figure 1. The four parts comprise of three important elements referred to as ‘Catchment Area’ which describes the identification of the areas and type of roads covered in this study, ‘Data Set’ which explains the source and size of data and ‘Data Analysis’ which refers to the analyses conducted throughout the study.
2.1 Catchment Area
The catchment areas for the study involved Malaysian nationwide which comprises all 14 states which consists of types of roads which are the expressways, federal roads, state roads, municipal roads and others. The criterion was chosen because trees are available along the road shoulder in all road types in Malaysia and certainly represent Malaysia’s actual scenario of single vehicle collisions involving trees.

2.2 Data Set
The data for this study was retrieved from Polis DiRaja Malaysia (PDRM) Traffic Department through Pol 27 form. Pol 27 data is valid due to the fact the PDRM is the primary authority for road accident investigation and that Pol 27 form has been used by PDRM for five years to date. The softcopies of Pol 27 data from the PDRM database was transferred to the national accident database at MIROS before data cleaning and analysis was done. After data cleaning and filtering, a total of 101 tree-related accident cases which comprised fatal, severe and slight injury cases for year 2006 (47 cases) and 2007 (54 cases) were finally retrieved.

2.3 Data Analysis
The overall data for year 2006 and 2007 was analyzed using Statistical Package for the Social Sciences (SPSS) software and Microsoft Excel. Analysis of comparison between the data sets from the two years was made to determine the outcome pattern and to determine any discrepancy of the analyzed variables from both sets of population. Afterwards, cross tabulation was conducted to evaluate the odds ratio value of each identified crucial factor to identify the ratio of likelihood of being fatal between two segregated variables of the respective factor. Each variable was grouped in such a way to have a balanced distribution of number of cases to one another.

3 RESULTS & DISCUSSIONS
3.1 Contributing Factors in Tree Related Collision for Year 2006 & 2007
Overall, Pol 27 contains a total of 91 variables. However, after considering the number of available data and filtering the under-reported cases, this study looks into seven contributing factors for tree related collisions available from Pol 27.

47 tree-related collision cases were reported in year 2006 in Malaysia. This comprises 15 fatal cases and 12 severe injury cases (31.9% and 25.5% respectively). In year 2007, 24 (44.4%) fatal cases and 14 (25.9%) severe injury cases were recorded from a total of 54 cases. The distributions of the cases for each year is shown in the table below, in accordance to the contributing factors which will be focused in this study.
Further in the study, each crucial factor was then correlated with the collision severity which was divided into fatal and non-fatal collisions. From the chi-square test, the authors were able to determine whether the factor is or is not associated with severity. The association is significant when the Asymp. Sig. value is <0.05 which means that a particular factor does have a significant effect to the level of severity of the collision.

Moreover, cross tabulation analysis was done to look into the detailed distribution of the number of cases and percentage for each variable in each factor, and to measure the odds ratio value and chi-square Asymp. Sig. value for each factor. The odds ratio value was needed to identify the ratio of likelihood to be fatal when involved in tree-related collisions. By using the odds ratio, the authors can identify the more severe variable in each of the studied factors with the confidence level of 95%.

3.2 Comparison of tree related traffic collisions for year 2006 & 2007
In this section of the report, the authors would like to observe the trend of pattern between the two independent samples which are the tree-related collisions between 2006 and 2007 retrieved from Pol27. The data was in ordinal format and for that reason, Mann-Whitney U Test was been applied.

Table 2: Mann-Whitney U Test result of Year 2006 & 2007 Pol 27 data

<table>
<thead>
<tr>
<th>Mann-Whitney U</th>
<th>Asymp. Sig. (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1144.500</td>
<td>0.389</td>
</tr>
<tr>
<td>1023.000</td>
<td>0.053</td>
</tr>
<tr>
<td>1248.500</td>
<td>0.874</td>
</tr>
<tr>
<td>1109.000</td>
<td>0.170</td>
</tr>
<tr>
<td>519.000</td>
<td>0.000</td>
</tr>
<tr>
<td>117.500</td>
<td>0.000</td>
</tr>
<tr>
<td>1105.500</td>
<td>0.239</td>
</tr>
</tbody>
</table>

Grouping Variable: Year (2006 & 2007)

Out of seven variables analyzed, only two variables which are the numbers of carriageways and pavement quality - had the Asymptotic Significance value (p value) lower than 0.05. The
significant values signify a significant distinction between the data of the similar variables from the two populations.

Based from the authors’ perception, the reason behind for the two years data pattern discrepancy for the two said variables was due to the effect of road upgrading. Interventions such as road improvement, for example upgrade for number of carriageways and surface treatment of road pavement at a particular site may influenced the pattern of the data. Where else, other remaining variables would need more massive interventions to change the current condition of a particular location or even is unlike to vary within a year period.

The other five variables recorded insignificant $p$ value which means that the result had similar pattern and that the data had no differentiation between the two years. For that reason, during further analysis in this study, the six said variables with no significant distinction between the two years will be combined as one, while the two variables with significant variance between the two years period will be analyzed separately.

3.3 Demographic Data of the Drivers
A total of 47 cases from 2006 and 54 cases from 2007 were collected. From the accident cases, fatal tree-related cases comprised 31.9% in 2006 and 44.4% in 2007 of the total number, higher than severely-injured and slightly-injured cases.

Table 3: Collision severity according to drivers’ gender for year 2006 and 2007

<table>
<thead>
<tr>
<th>Gender</th>
<th>Year 2006</th>
<th></th>
<th></th>
<th>Year 2007</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
<td>Non Fatal</td>
<td>Total case</td>
<td>Fatal</td>
<td>Non Fatal</td>
<td>Total case</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13 (27.7%)</td>
<td>21 (44.7%)</td>
<td>34 (72.3)</td>
<td>19 (38.8%)</td>
<td>23 (42.6%)</td>
<td>42 (85.7)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2 (4.3%)</td>
<td>11 (23.4%)</td>
<td>13 (27.7)</td>
<td>3 (5.6%)</td>
<td>4 (7.4%)</td>
<td>7 (14.3)</td>
<td></td>
</tr>
<tr>
<td>Total driver</td>
<td>47 (100%)</td>
<td>49 (100%) * 5 under reported cases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From the data, for year 2006, 34 (72.3%) out of 47 drivers involved in tree-related collisions were male drivers. This is much higher compared to female drivers which only constituted 27.7% of the total drivers. From the total number of male drivers involved, 61.9% engaged in fatal crashes.

For year 2007 data, out of the 54 cases, 5 cases did not have information on drivers’ gender. However, from the remaining 49 drivers, 42 were male (85.7%) while female only comprises 14.3%. From the available data shown in Table 3, when focus to the fatal tree related cases, male drivers constitute around 86% of the total number of drivers involved in fatal tree related cases. The pattern is identical to the findings by Haworth et al. (1997) which revealed that male drivers constituted 80% of fatal single vehicle collision in Australia.

Table 4: Drivers age details

<table>
<thead>
<tr>
<th>Group of Age</th>
<th>Count 2006</th>
<th>Count 2007</th>
<th>Percentage (Count/Total Cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 - 25</td>
<td>25</td>
<td>18</td>
<td>56.82% 45%</td>
</tr>
<tr>
<td>26 - 30</td>
<td>6</td>
<td>4</td>
<td>13.64% 10%</td>
</tr>
<tr>
<td>31 - 35</td>
<td>7</td>
<td>3</td>
<td>15.91% 7.5%</td>
</tr>
<tr>
<td>36 and above</td>
<td>6</td>
<td>15</td>
<td>13.64% 37.5%</td>
</tr>
</tbody>
</table>

Table 4 describes the age of the drivers involved in tree-related cases for the studied two years. The data shows that the group age of (16-25) contributed to more than 45% for each respective year. The result is similar to the pattern for fatality trend according to the age of victims in Malaysia which showed that age group of 16-20 and 21-25 recorded the highest number of fatality in road traffic collisions in Malaysia (PDRM 2000).
3.3.2 Casualties and injuries of the drivers
Fatally injured drivers constituted 21.3% (2006) and 26.8% (2007) from the total said cases. 13 cases in the year 2007 do not have enough information available.

Table 5: Types of Injuries to Drivers

<table>
<thead>
<tr>
<th>Injured Body Part</th>
<th>Count</th>
<th>Percentage(Count/Total Cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>Head</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Torso</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Upper extremities</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Non Injury</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5 revealed that drivers mostly injured their heads in tree-related crashes. Two possible contributors of head injuries are whiplash and hitting the windscreen, with the latter associated with unbelted drivers. The present data could not be cross tabulated with belted/unbelted drivers since many seatbelt wearing data were not available.

Table 6: Restraint Device Wearing and Associated Injury Severity

<table>
<thead>
<tr>
<th>Restraint Device Wearing</th>
<th>Injury Severity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belted (54 drivers)</td>
<td>Non</td>
<td>16.7%</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>42.6%</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>22.2%</td>
</tr>
<tr>
<td></td>
<td>Fatal</td>
<td>18.5%</td>
</tr>
<tr>
<td>Unbelted (21 drivers)</td>
<td>Non</td>
<td>4.8%</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>38.1%</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>28.6%</td>
</tr>
<tr>
<td></td>
<td>Fatal</td>
<td>28.6%</td>
</tr>
<tr>
<td>Helmet worn (8 riders)</td>
<td>Non</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>Fatal</td>
<td>0%</td>
</tr>
<tr>
<td>Helmet unworn (5 riders)</td>
<td>Non</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Minor</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>Fatal</td>
<td>100%</td>
</tr>
</tbody>
</table>

Cases in 2006 and 2007 are combined and tabulated as shown in Table 6. However, 13 cases did not have data available. From the table, it is observed that unbelted drivers had higher risk of getting severe injuries and fatalities compared to drivers wearing seatbelts. Belted drivers had a significant percentage of non-injury higher than the unbelted with 11.9% difference. Also from the table, the numbers also illustrated the significant probability of survival if one is wearing a helmet during a tree-related collision. Nonetheless, the results signify the importance of restraints devices usage such as seat belts and helmets in limiting the level of injury severity in tree related road traffic collisions.
3.4 Analysis of Contributing Factors in Tree Related Collision for Year 2006 & 2007

3.4.1 Day and Time Factors

Table 6: The Relationship between Tree Related Collision Severity and Day of Occurrence

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
<th></th>
<th>Odds Ratio</th>
<th>chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>Cases</td>
<td>Fatal</td>
<td>Non Fatal</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Weekday (WD)</td>
<td>%</td>
<td>17</td>
<td>28</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>16.8%</td>
<td>27.7%</td>
<td>44.5%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>39</td>
<td>62</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>38.6%</td>
<td>61.4%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Weekends= Friday, Saturday, Sunday          Weekdays=Others

From Table 6, it was found out that weekend recorded a higher frequencies of tree-related collision with 56 cases (55.4%) compared to 44.5% during weekdays. The result could be caused by the bigger number of vehicles utilizing the roads during weekends thus increasing the exposures of road collisions which then contribute to the increase in tree related collisions. The findings also supports the findings of a study done by Haworth et al. (1997) which stated that Sunday and Saturday were the most common days for single-vehicle collisions (23% and 20%). Odds ratio value of 1.066 signifies that weekend is 1.066 times more likely to involve in fatal tree-related collisions compared to weekdays.

When zoomed to fatal cases, weekend contribute to 56.4% of the overall fatal tree-related collisions in both years. The outcome pattern however shows a slightly lower number compared to the findings by Mok et al. (2006) which stated that greater than two-thirds of fatal tree-related collisions occurred on Fridays and weekends.

Nevertheless, results from chi-square test proved that the association between day factor and collision severity is not significant. In other words, the effect of type of day does not contribute a major involvement to affect severity.

Table 7: The Relationship between Tree Related Collision Severity and Time of Occurrence

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
<th></th>
<th>Odds Ratio</th>
<th>Chi Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Cases</td>
<td>Fatal</td>
<td>Non Fatal</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Nighttime (NT)</td>
<td>%</td>
<td>25</td>
<td>22</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>24.8%</td>
<td>21.8%</td>
<td>46.5%</td>
<td></td>
</tr>
<tr>
<td>Daytime (DT)</td>
<td>Cases</td>
<td>14</td>
<td>40</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>13.9%</td>
<td>39.6%</td>
<td>53.5%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>39</td>
<td>62</td>
<td>101</td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>38.6%</td>
<td>61.4%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Daytime= 6 a.m. – 6 p.m.       Nighttime= 6.01 p.m. – 5.59 a.m.

Based from the findings in Table 7, Chi-square test showed a significant value of 0.005 which indicates that time factor plays an important contribution to influence the level of severity in tree related collisions. However, the result shows a contrary pattern to the result of a study by Haworth et al. (1997) which found that more single vehicle collisions occurred at night (6 p.m. till 6 a.m.) than during the day (6 a.m. till 6 p.m.).

Conversely, when focusing into fatal collisions, nighttime period recorded a significantly higher frequency. This was supported by a study by Kloeden et al. (1999) which proved that nighttime single vehicle collisions were much more likely to involve a road shoulder hazard, which fatally injured a car occupant than were daytime collisions.

In addition, from odds ratio value it was identified that nighttime tree related collision is 3.25 times more likely to be fatal than during daytime. This indicates similarity to the result from Kloeden et al. (1999) study mentioned above.
3.43 Road Environment Factors

Table 8: The Relationship between Tree Related Collision Severity and Area Type

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
<th></th>
<th></th>
<th>Odds Ratio</th>
<th>chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban &amp; Suburban (US)</td>
<td>Cases</td>
<td>19</td>
<td>21</td>
<td>40</td>
<td>1.723</td>
<td>0.183</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>18.8%</td>
<td>20.8%</td>
<td>39.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural (R)</td>
<td>Cases</td>
<td>21</td>
<td>40</td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>20.8%</td>
<td>39.6%</td>
<td>60.4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>40</td>
<td>61</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>39.6%</td>
<td>60.4%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8 shows the relationship between the severity level of tree related collisions with the type of area where the collision occurred. From the table, it is revealed that rural areas recorded more than 60% of the overall number of tree related collisions in both years. When referring to the result of a study by Haworth et al. (1997) which found out that collision involving trees at rural areas recorded 67%, the outcome showed a similar pattern.

The nature of the Malaysian environmental climates with tropical forests comprising the majority of the rural areas and the fact that trees are the most common type of object can be found along Malaysian roads could have influenced the findings mentioned above. Although literatures also proved that trees were also the most common roadside object in the metropolitan areas, the lower design speed and the installation of street lights along the municipal roads might have facilitate drivers. Where else, visibility problem due to non existence of street lights along rural roads could have contributed to the high number in tree related collision at rural areas.

However, based from the odds ratio value, it is revealed that tree related cases at urban and suburban areas are 1.7 times more likely to involve fatality compared to rural areas. The findings show resemblance to the result of a study done by Kloeden et al. (1999) in South Australia which also proved that fatal single vehicle collisions involving road side hazards were higher at metropolitan areas compared to rural. The results from both studies illustrate a trend of higher fatal roadside hazard involvement rates at lower speed limit roads. This is likely to be due to more roadside objects adjacent to lower speed roads and that lower speed roads such as municipal roads usually have more limited clearance zones.

Table 9: The Relationship between Tree Related Collision Severity and Road Geometry

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
<th></th>
<th></th>
<th>Odds Ratio</th>
<th>chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Geometry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curve &amp; Junction (CJ)</td>
<td>Cases</td>
<td>12</td>
<td>18</td>
<td>30</td>
<td>1.087</td>
<td>0.852</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>11.9%</td>
<td>17.8%</td>
<td>29.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight (S)</td>
<td>Cases</td>
<td>27</td>
<td>44</td>
<td>71</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>26.7%</td>
<td>43.6%</td>
<td>70.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>39</td>
<td>62</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>38.6%</td>
<td>61.4%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Straight stretches record an obvious higher frequency of cases as shown is Table 9. In the authors’ perception, this could be due to result of driving behavior. Drivers would tend to drive faster on straight stretches due the comfortable environmental conditions and in contrast, tend to be more alert when negotiating curves which will contributes to speed reduction and lower the possibility of involving in a road collision.

Nevertheless, the proportion of fatal tree related cases was slightly higher at curves with 40% rather than 38% at straight stretches. Overall, the pattern is similar to the findings of a study by Kloeden et al. (1999) which stated that the number of collisions were higher on straight stretches rather than at curves, although the percentage of fatalities are higher at curves.
Furthermore, from the analysis it was discovered that tree related collisions at curves are 1.087 times higher than on straight stretches to involved fatalities. However, from chi-square value it was found out that road geometry does not have a significant association with collision severity.

Table 10: The Relationship between Tree Related Collision Severity and No. of Carriageways according to year: (a) year 2006, (b) year 2007.

2006

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Carriageway</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>Dual (D)</td>
<td>Cases</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>29.8%</td>
</tr>
<tr>
<td>Single (S)</td>
<td>Cases</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>2.1%</td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>31.9%</td>
</tr>
</tbody>
</table>

2007

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Carriageway</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>Dual (D)</td>
<td>Cases</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Single (S)</td>
<td>Cases</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Total</td>
<td>Cases</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>44.4%</td>
</tr>
</tbody>
</table>

From the odds ratio values for both years, dual carriageway roads recorded higher level of severity as shown in Table 10. This could be due to the fact that, in dual carriageways roads, there are situations where large trees are even planted along the road median, especially along municipal roads. The situation is even more hazardous than if the trees are available along road shoulders. This is because, trees along medians have a closer distance to the roadway and this might limit the response time and bound the available space for drivers to react during emergencies.

In contrast, on a single carriageway road, the non existence of medians would provide more space and time for drivers to react during collision. Longer action time and wider space will assist in lowering the impact speed and thus reducing the \(\Delta V\) value which is related to the damage severity of the vehicle. Consequently, a lower level of intrusion to the vehicle would reduce the injury severity level for the occupants.

Conversely, in a general point of view, single carriageway roads would have a higher severity level tree related collisions compared to dual carriageways. The stand point is acceptable for incidents which the vehicles only engaged with trees along the shoulders roads at the same traveling direction with the vehicle and do not involve vehicle crossing over into the opposite lane. Therefore, the result above is essential to highlight the effects of median during a tree related collision which involved cross over conditions.
Table 11: The Relationship between Tree Related Collision Severity and Pavement Quality according to year: (a) year 2006, (b) year 2007.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th>Pavement</th>
<th>Fatal</th>
<th>Non Fatal</th>
<th>Total</th>
<th>Odds Ratio</th>
<th>chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good &amp; Flat (GF) Cases</td>
<td></td>
<td></td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Wavy &amp; Holed (WH) Cases</td>
<td></td>
<td></td>
<td>15%</td>
<td>32%</td>
<td>47%</td>
<td>2.00</td>
<td>0.462</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>15%</td>
<td>32%</td>
<td>47%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Both cross tabulation in Table 11 supported the result in the previously performed Mann-Whitney test which found out that the pattern varied between both years data. For year 2006, all tree related collisions only occurred on wavy pavement roads. Thus, the chi-square test and odds ratio could not be calculated since the pattern was constant. However, in 2007 it was discovered that wavy pavement roads are two times more likely to have fatal tree related collisions compared to good conditioned roads.

The insignificant chi-square value of 0.462 for 2007 data and the constant pattern of collision in 2006 data proved that pavement condition is not associated with collision severity. However, high probability of fatality at wavy and holed pavement roads is revealed in 2007 data. Wavy pavement might give difficulties for drivers to control their vehicle and holed pavement would cause hydroplaning issues during raining which will result in traction loss to vehicles’ tire grip.

Table 12: The Relationship between Tree Related Collision Severity and Road Shoulder Width

<table>
<thead>
<tr>
<th>Factor</th>
<th>Collision Severity</th>
<th>Road shoulder Width</th>
<th>Fatal</th>
<th>Non Fatal</th>
<th>Total</th>
<th>Odds Ratio</th>
<th>chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good &amp; Flat (GF) Cases</td>
<td></td>
<td>&lt; 2.5 m (L)</td>
<td>22</td>
<td>20</td>
<td>42</td>
<td>2.700</td>
<td>0.010</td>
</tr>
<tr>
<td>Wavy &amp; Holed (WH) Cases</td>
<td></td>
<td>&gt;=2.5 m (M)</td>
<td>17</td>
<td>42</td>
<td>59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>39</td>
<td>62</td>
<td>101</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: >= 2.5 m = Expressways & Federal roads <2.5 m = State roads, municipal roads & others

Overall, roads with road shoulder width larger than 2.5 meters (federal roads and expressways) recorded the higher number of tree related collisions of 59 cases, as shown in Table 12. The condition might be due to the fact that in Malaysia, federal roads contribute the highest proportion of road traffic collisions with approximately 38.1% from the total number of road traffic collisions between 1997 till 2000 (PDRM 2000). This scenario could possibly leads to the high percentage of tree related collisions in the said type of roads.

Nonetheless, focusing to fatal collisions, roads with road shoulder width less than 2.5m (state roads and others) recorded higher portion compared to expressways and federal roads.
This might cause by the affect of guardrail installation or the availability of wider clearance zones especially along expressways compared to state roads, municipal roads and others.

Generally, expressways often have a wider space or nearer to the optimum range of 6 to 9 meters for clearance zones compared to other types of roads in Malaysia and this have proved its effect. Although the total number of tree related collisions was higher at roads with shoulder width more than 2.5 meters, the likelihood of having fatal collisions was 2.7 times higher at roads with shoulder width less than 2.5 meters. The findings signified the importance of a wider road shoulder width and the installation of proper crash barriers and guardrails to lower the possibility of suffering fatal injuries in a tree related collision.

Wider road shoulder width provides more time for vehicles to slow down and for drivers to react during emergency situations while guardrails offer energy absorption mechanism for vehicles during collisions. Nevertheless, chi-square test result also recorded a significant value of 0.01 which indicated that road shoulder width does have an important effect to the severity level of tree related collisions.

4. CONCLUSION
The study looked into seven contributing factors of tree related collisions which are day, time, area type, road geometry, numbers of carriageway, pavement quality and road shoulder width, all were gathered from Pol 27 investigation form. From a non-parametric analysis performed on tree related collisions data of year 2006 and 2007, only pavement quality and numbers of carriageways have significant variation in the distribution of number of cases between the two years. The findings in this study also proved that out of the seven studied variables, only time and road shoulder width are associated to injury severity level for collisions involving trees. Nighttime, dual carriageways roads, wavy and holed condition roads and roads with road shoulder width below 2.5 m were found as the more influential variables with significant values of odds ratio to cause fatal collisions. The recent study also revealed that a collision with a tree during nighttime is 3.25 times more likely to cause fatalities than during daytime. This may be strongly due to the driver’s low visibility at night. Low driver’s visibility and possible drowsiness due to driving during normal sleeping hours can lead to a high possibility of run-off-road (ROR) collision which could result in a collision with road furniture and hazardous rigid objects such as trees. Furthermore, from the findings of this study, it is revealed that the possibility of fatal tree related collisions on dual carriageway road is three times higher than on roads with single carriageway. Trees are occasionally planted along the median of dual carriageway roads. Thus, that would increase the risk exposure for vehicles to collide with trees along the median when encountering an ROR collision. When looking at the pavement quality factor, the study proved that the risk of fatal collision on wavy and holed condition roads is two times higher than on good and flat condition roads. Wavy pavement causes drivers to face difficulties in controlling the vehicles and the holed pavement forms water puddles during rain which causes the vehicle’s tires to lose grip. Furthermore from the study, it was found out that collisions on a road with road shoulder width less than 2.5 m is 2.7 times more likely to cause fatalities. The result of wider clearance zones and guardrail installation contributed to lower frequencies of fatal tree related collision along roads with road shoulder width above 2.5 m. These are the variables that need to be prioritized in future interventions to reduce the severity level of tree related collisions in Malaysia.
REFERENCES


Morris, A, Truedsson, N, Stallgarth, M, & Magnisson, M (1999), Injury Outcomes in Pole/Tree Crashes, A Research Project for Monash University Accident Research Centre and Halmsted University.


ABSTRACT
This paper addresses the reality and requirements of traffic safety in the UAE. Different traffic safety issues in the country are discussed including traffic accidents, traffic violation, traffic safety education and awareness, vehicular safety, infrastructural factors, supporting institutional factors, driving behavior, emergency medical service, accident research, and the roles of traffic safety stakeholders. The opinions of road users as well as professionals dealing with traffic safety were collected and analyzed. Meanwhile, different facts from the recent accident reports are analyzed. Results revealed that the major causes of traffic safety problems are (1) negative behavior of road users, (2) lack of awareness of road users, (3) faulty road design, (4) faulty vehicle, (5) inadequate training of drivers, (6) poor law enforcement, and (7) inadequate coordination among traffic safety stakeholders. Traffic safety in the UAE could be improved by establishing a national traffic safety authority. Other recommendations include establishing educational programs at schools, conducting a continuous awareness campaign, implementing a systematic road safety auditing, performing periodical evaluation of traffic laws, applying a strict law enforcement, introducing more monitoring devices for traffic violations, and initiating an in-depth traffic accident and traffic violation research.

1 INTRODUCTION
Research on road safety proves that accidents are predictable, and therefore, could be avoided. At least, efforts could be made to minimize the consequences, injuries and fatalities of accidents. The understanding of the nature and dimensions of the traffic safety matrix is quite essential to identify the accident leading causes and ways of effective prevention. Over the past two decades many developed countries were successful in studying the road safety aspects, and establishing strategies and effective methods to reduce traffic accidents causalities and fatalities. Sweden, for example, has developed a strategic plan to achieve zero deaths from traffic accidents, known by “Vision Zero” (Vägverket, 2006).

The reality of traffic safety, in its broad sense, cannot only be captured by simple statistical numbers indicating rates of casualties and fatalities. Reality involves several aspects including, for instance, effectiveness of law enforcement, spread and effectiveness of traffic
awareness programs, roles and needs of stakeholders, and effectiveness of coordination among underlying agencies.

Research on traffic safety issues started around 1930s by the introduction of the so-called "Heinrich's Domino model". The model was initially intended for occupational safety purposes, but was found useful for accident-injury analysis. As described by Andersson (1999), this model takes the form of five domino bricks in a row, representing: 1) environment, which influences the 2) human activities, that originates 3) hazards, which cause 4) accidents, leading to 5) injuries. The idea behind the domino analogy is to illustrate causing factors as a liner flow of time-ordered stages or events. Meanwhile, this mechanism provides the options (for primary and secondary preventions), by intervening in the various stages of the flow process. For example, most of primary-roadway traffic safety intervention strategies could be sought to intervene between environment, human activities and hazards (e.g. seatbelts, airbags, etc.).

Another model (Epidemiological Model) was initially developed from the perspective of infectious diseases, which is largely reflected in its vocabulary and methods. For that reason, the model defines accidents as an epidemic disease of non-communicable nature (Farmer and Miller, 1995). Accordingly, accidents are seen as if they have their own natural history, and follow the same epidemiological pattern as any other infectious disease - that is, the agent, the host and the environment interacting together to produce injury or damage (Andersson, 1999). This model is built upon the theoretical basis of epidemiology and uses the same construct. Those constructs have helped to identify road traffic accident risk factors and consequences, defining their frequencies and trends and determining what safety measures could be elaborated for preventive purposes in most countries in the world. Examples of preventive strategies include drivers' education, legislation (e.g. seatbelts and safety helmets for cyclists), improvement of roadway engineering, etc. The model is very popular among public health scientists and is a dominant approach in accident-injury research (Ahmed, 2002).

The Haddon Model was built upon the basis of the Heinrich’s Domino and the Epidemiological Model (Andersson, 1999). William Haddon applied the principles of public health and epidemiology, and the Heinrich’s principles of accident analysis, to the problem of traffic-safety and injury prevention. The major contribution (by Haddon) was that in spite of the perceived ‘unpredictiveness’ of accidents, Haddon decided that “they should be addressed, analysed and understood by means of scientific approaches used in epidemiology”.

The major contribution of Haddon was his innovation of a matrix of four columns and three rows (Table 1). This matrix combines the public health concepts of host-agent–environment, the dimension of time as targets of change, and the concepts of primary, secondary and tertiary prevention (Haddon, 1980). More specifically, the factors defined by the columns in the matrix refer to the interacting factors that contribute to the injury process. The host column refers to the person at risk of injury. The agent of injury is energy (e.g. mechanical, thermal, electrical etc.) that is transmitted to the host through the vehicle (inanimate object) or vector (person or other animal). Physical environments include all the characteristics of the setting in which the injury event takes place (for example a roadway, building, playground, or sports arena). Social and political norms in the cultural environment are referred to as the social environment. These nine boxes (shaded in Table 1) give a possible focus of attack on elements of the road trauma problem. Table 1 also presents the factors that contribute to crashes in the road traffic system.
Table 1: The Haddon Matrix (Haddon, 1980)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Factors</th>
</tr>
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<tr>
<td></td>
<td>Human</td>
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<tr>
<td>Pre-crash</td>
<td>Information</td>
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<tr>
<td></td>
<td>Attitude</td>
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<td></td>
<td>Impairment</td>
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<td></td>
<td>Police enforcement</td>
</tr>
<tr>
<td>Crash</td>
<td>Use of restraints</td>
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<tr>
<td></td>
<td>Impairment</td>
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<tr>
<td>Crash-protective during the</td>
<td></td>
</tr>
<tr>
<td>crash</td>
<td>Seat belts</td>
</tr>
<tr>
<td></td>
<td>Occupant restraints</td>
</tr>
<tr>
<td></td>
<td>Other safety devices</td>
</tr>
<tr>
<td></td>
<td>Crash-protective design</td>
</tr>
<tr>
<td>Post-crash</td>
<td>First-aid skill</td>
</tr>
<tr>
<td></td>
<td>Access to medics</td>
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<tr>
<td></td>
<td>Ease of access</td>
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<td></td>
<td>Fire risk</td>
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<tr>
<td></td>
<td>Rescue facilities</td>
</tr>
<tr>
<td></td>
<td>Congestion</td>
</tr>
</tbody>
</table>

In the SUPREME (SUmmary and Publication of Best Practices in Road Safety in the EU - MEember States plus Switzerland and Norway) project, the European Commission (European Commission, 2007) categorized the main road safety measures by nine themes; namely (1) education and campaign, (2) driver education, training and licensing, (3) rehabilitation and diagnostics, (4) vehicles, (5) infrastructure, (6) enforcement, (7) statistics and in-depth analysis, (8) institutional organisation of road safety, and (9) post accident care.

The items to characterise the traffic safety status do not only compromise statistical measures of accidents, fatalities and violations. A broader vision may be sought through the critical assessment of other fundamental safety elements such as law enforcement, education, training, etc. To investigate the status of traffic safety in the UAE, the following issues were selected that nearly cover all the items involved in traffic safety.

1. Traffic accidents and fatalities
2. Traffic violation statistics
3. Traffic safety education and awareness
4. Traffic laws
5. Vehicular safety
6. Driving behaviour
7. Infrastructural factor
8. Supporting institutions
9. Emergency medical service
10. Traffic safety stakeholders and their roles
11. Opinion about independent institution
12. Accident and violation data analysis
13. Driver’s training and licensing process
14. Causes of traffic safety problems
15. Improvements needed for traffic safety

2 METHODOLOGY

The study adopts a simple methodology of data collection, analysis and interpretation. Data were collected from both primary and secondary sources. The study tools and the primary sources of data included a user survey and an expert (professional) interview. In the user survey, a total of 2397 samples were collected from all over the UAE to investigate users’ perceptions on different traffic safety issues. Interviews (total 129 all over the UAE) were conducted on professionals working with different stakeholders like police, municipalities,
transport authorities, health authorities, etc. Beside this, related statistics from the annual UAE police reports were utilized and were compared to corresponding numbers in other countries. Table 2 shows the sources of information of the selected traffic safety issues.

Table 2: Sources of information collected for the traffic safety issues in the UAE

<table>
<thead>
<tr>
<th>SI No.</th>
<th>Traffic Safety Issues</th>
<th>Primary sources</th>
<th>Secondary sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Road User Survey</td>
<td>Stakeholder Interview</td>
</tr>
<tr>
<td>1</td>
<td>Traffic accidents and fatalities</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>2</td>
<td>Traffic violation statistics</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>3</td>
<td>Traffic safety education and awareness</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>4</td>
<td>Traffic laws</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>5</td>
<td>Vehicular safety</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>6</td>
<td>Driving behaviour</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>7</td>
<td>Road infrastructural factor</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>8</td>
<td>Supporting institutions</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>9</td>
<td>Emergency medical service</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>10</td>
<td>Traffic safety stakeholders and their roles</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>11</td>
<td>Opinion about independent institution</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>12</td>
<td>Accident and violation data analysis</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>13</td>
<td>Driver’s training and licensing process</td>
<td></td>
<td>✔</td>
</tr>
<tr>
<td>14</td>
<td>Causes of traffic safety problems</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>15</td>
<td>Improvements needed for traffic safety</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

3 STATUS OF TRAFFIC SAFETY
3.1 Traffic Accidents and Fatalities
In 2008, the total number of accidents that cause injury was 10135; whereas in 2007 it was 8828 and in 2006 it was 8443 (Table 3). Some other key statistics of traffic accidents during 2004 to 2008 in the UAE are shown in Table 3.

Table 3: Key statistics of traffic accidents in the UAE (UAE MOI, 2004-2008)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of accidents that cause injury</td>
<td>8269</td>
<td>9805</td>
<td>8443</td>
<td>8828</td>
<td>10135</td>
</tr>
<tr>
<td>Total number of injuries</td>
<td>10233</td>
<td>12365</td>
<td>11552</td>
<td>11935</td>
<td>13221</td>
</tr>
<tr>
<td>Total number of fatalities</td>
<td>824</td>
<td>604</td>
<td>878</td>
<td>1024</td>
<td>1071</td>
</tr>
<tr>
<td>Fatalities per 100,000 population</td>
<td>19.07</td>
<td>12.98</td>
<td>20.81</td>
<td>22.82</td>
<td>23.28</td>
</tr>
<tr>
<td>Fatalities per 100,000 registered vehicles</td>
<td>57.28</td>
<td>39.26</td>
<td>56.29</td>
<td>55.55</td>
<td>N/A</td>
</tr>
<tr>
<td>Fatalities per 100,000 licensed drivers</td>
<td>330.72</td>
<td>220.70</td>
<td>285.46</td>
<td>348.81</td>
<td>N/A</td>
</tr>
</tbody>
</table>

It is worth noting that the accident fatality rates in the UAE have been over reported by the World Health Organization (WHO, 2009). The reported rates in (WHO, 2009) were based on a prediction model and accounting for potential of missing data. The police rates for 2008 were about 22.82 fatalities/100000 population. Table 4 (extracted from WHO, 2009) compares traffic death rates in various countries including the UAE. The table shows that the traffic accident death rate in the UAE (37.1 per 100,000 population according to WHO model-based rates) is higher than that in neighboring countries like Oman, Qatar and Kuwait. In this regard, the UAE police reports would be considered a more reliable source of information.
Even with this lower rate, the UAE should and is actually undertaking major steps to achieve comparable rates to those of Sweden, France, Germany, UK, and Netherlands.

Table 4: Comparison of road traffic death rates among the countries (WHO, 2009)

<table>
<thead>
<tr>
<th>Country</th>
<th>Reported number of traffic deaths (2007)</th>
<th>Modeled number of traffic deaths</th>
<th>Estimated road traffic death rate per 100 000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reported number of traffic deaths (2007)</td>
<td>Modeled number of traffic deaths</td>
<td>Estimate point estimate</td>
</tr>
<tr>
<td>France</td>
<td>4620</td>
<td>4620</td>
<td>7.5</td>
</tr>
<tr>
<td>Germany</td>
<td>4949</td>
<td>4949</td>
<td>6.0</td>
</tr>
<tr>
<td>Japan</td>
<td>6639</td>
<td>6639</td>
<td>5.0</td>
</tr>
<tr>
<td>Kuwait</td>
<td>482</td>
<td>482</td>
<td>16.9</td>
</tr>
<tr>
<td>Netherlands</td>
<td>791</td>
<td>791</td>
<td>4.8</td>
</tr>
<tr>
<td>Oman</td>
<td>798</td>
<td>553</td>
<td>347-920</td>
</tr>
<tr>
<td>Qatar</td>
<td>199</td>
<td>199</td>
<td>23.7</td>
</tr>
<tr>
<td>Sweden</td>
<td>471</td>
<td>471</td>
<td>5.2</td>
</tr>
<tr>
<td>UAE</td>
<td>1056</td>
<td>1626</td>
<td>912-2570</td>
</tr>
<tr>
<td>UK</td>
<td>3298</td>
<td>3298</td>
<td>5.4</td>
</tr>
<tr>
<td>USA</td>
<td>42642</td>
<td>42642</td>
<td>13.9</td>
</tr>
</tbody>
</table>

According to the UAE police report, the major type of injury is classified as fatal, serious, moderate and minor. Figure 1 shows the type of injury during 2005 to 2008. The figure shows that the percentage of fatalities almost increased over the past years; in 2005 it was 4.9% and in 2008 it was 8.1%. The percentage of minor injuries also increased which eventually decrease the share of moderate and serious injuries.

Figure 1: Types of injuries from traffic accident in the UAE from the year 2005 to 2008

Figure 2 shows the distribution of injuries in the different emirates of the UAE in 2008. The figure shows that a large portion of the accidents in Sharjah are fatal (16.5%), serious (13.2%) or moderate (40%) injuries. In Ajman, moderate injuries (57.9%) are prominent.
Figure 2: Distribution of accidents by type in the different emirates of the UAE in the year 2008.

About 59% of the respondents (to the road user’s survey) indicated that they were involved in at least one traffic accident in their lifetime. Among these reported accidents (in the user survey form), 68% had no injuries (only vehicle damage), 18% were involved in minor injury crashes, 9% were involved in moderate-injury crashes, 4% were involved in serious-injury crashes, and 1% were involved in crashes that resulted in fatalities (Figure 3).

Figure 3: Types of accident involved by the respondents

Figure 4 illustrates the main causes of accidents from the year 2005 to 2008, according to the UAE police reports (UAE MOI 2005-2008). Obviously, the factors associated with the driver’s behaviour are the most important reasons for accidents and injuries.
3.2 Traffic Violation Statistics
One of the important elements of traffic safety is traffic violation. According to the UAE police report (UAE MOI 2005-2008), the total number of violations recorded in 2008 was 4,498,134. In the UAE, the most prominent violation type is speeding. According to the police report (UAE MOI 2008), about 53% speeding violations were recorded in 2008, compared to 67% in 2005. Figure 5 shows the major type of violations recorded from the year 2005 to 2008.

Figure 5 Distribution of major traffic violation types in the UAE from 2005 to 2008

About 62% of the respondents to the user’s survey indicated that they were involved in a traffic violation at least once in their lifetime. The major violations were speeding (53%), parking-related (21%), and non-use of seatbelt (8%).

3.3 Traffic Safety Education and Awareness
The user survey included several questions aiming at assessing the road user knowledge, education and awareness of the traffic safety issues. In response to a question on self-assessment of the awareness level of the traffic laws and regulations, 35% of the respondents indicated that they have a high level of awareness, 32% above average, and 24% have average awareness levels of the traffic laws and regulations.
The sources of traffic safety education (according to the respondents) are the driving schools (43%) and media (24%). About 11% of the respondent indicated that they have no traffic safety education. On the other hand, the best ways to obtain traffic safety education were identified as school curricula (50.2%) and media radio/TV (53.2%). Some respondents indicated other avenues like newspapers (23.4%) and internet (15.4%). Nearly, 76% of the respondents (to the road user survey) were able to identify the emergency phone number (999) correctly.

Throughout the professionals’ interviews, only 39% of the respondents indicated that they had adequate traffic safety education in their training academy. Most respondents (64%) indicated that the level of education they received is not adequate.

3.4 Opinion about the New Traffic Law
The UAE recently (March 2008) adopted a new traffic law, with more penalties/fines imposed on traffic violators. According to the road user survey results, only 73% of the respondents indicated the “knowledge” of the new traffic law. Among those, 62% are fully aware of the law regulations, 28% are partially aware, and 10% do not have enough information on the new traffic law regulations. These facts reveal a need for more comprehensive campaigns of the new traffic law regulations.

The road user survey’s respondents indicated various sources of information about the new traffic law; 45% indicated “friends”, 23.2% from leaflets, 37.7% from newspapers, 34.4% from radio/TV and 25.9% from the internet.

On how effective the new traffic law, 40% (of the respondents) indicated likely contributions to reduce crashes and traffic violations, 43% indicated contributions to some extent, and 17% suspected any reductions in traffic accidents. In the interview with experts, the majority of the police personnel (88%) indicated the likely contributions of the new traffic law in reducing traffic accidents and violations. About 36% of the respondents (of the road user survey) believe that the new law will positively change the driving behaviour of road users. 50% of the respondents indicated the likelihood of changing the driving behavior to some extent, and 14% indicated more likelihood to no change.

3.5 Vehicular Safety
People were asked about the most important factor(s) they consider when buying a vehicle. 60.3% of the respondents consider vehicle safety, 27.3% think about the price of the car, and 25% consider the cost of maintenance. Only 23% of the respondents referred to the vehicle as a potential contributing factor in the “loss-of-control” situations.

3.6 Driving Behaviour
Driving behaviour is an important aspect of traffic safety. In the user survey, people were asked several questions with about their behaviour with respect to wearing the seatbelt while driving, wearing seatbelt as a passenger, use of children safety seats, using the turning-lights indicators, following the speed limit, driving under the influence of drug or alcohol, yielding for pedestrians, yielding for bicycle and emergency vehicles, etc. Their responses about these behaviours are summarized in Figure 6.

About 55% of the respondents always wear seatbelts while driving and 16% wear them often. However, 7% of the respondents never wear seatbelts and 22% wear them sometimes. Numbers collected on the use of passenger seat belts are worse than those related to the use of drivers’ seat belt. Only 43% of the respondents always wear seatbelts as a passenger, 16% wear it most of the time, 25% wear it sometimes, and 16% never wear seat belt as passengers. The practice of using children safety seats is even worse. Only 39% of the respondents (that have children) use this regularly, but 35% never used it.
Most of the respondents have a good habit of using turning-light indicators. Nearly 58% always use indicators, 24% use them most of the times, while 5% never did. About 37% of the respondents always follow the speed limits and 35% follow it most of the times. However, 8% of the respondents indicated never following the speed limits, and 20% indicated sometimes.

Most of the respondents (60%) always yield for pedestrians while driving. Few respondents (5%) never yield for pedestrians. Yielding for bicyclists is relatively worse. Only 48% of the respondents always yield for bicyclists, but 7% never yield. Give-a-way to the ambulance or emergency vehicles is much better. Most of the respondents (84%) always yield to EMS vehicles.

Figure 6: Driving behaviour of the UAE road users
3.7 Road Infrastructural Factor
According to the user survey response, 57% feel that there might be problems in road alignments or road visibility that may cause traffic accidents. Respondents from Abu Dhabi (67%) and Al Ain (73%) feel this more than those from Dubai (39%).

3.8 Supporting Institutions
Different supporting institutes like driving schools and insurance companies are involved directly or indirectly in traffic safety operations. User survey respondents are not that much satisfied with the quality of driving schools. Only 28% of the respondents are satisfied, 41% consider the quality of service is moderate, and 17% are not satisfied. On the other hand, people requested improvements on the reliability of the insurance companies. Only, 13% of the respondents think those are reliable and 52% urge for improvements in insurance companies.

3.9 Emergency Medical Service
Emergency medical service (EMS) system is one of the important issues for post crash management. According to the interview of the health authority officials, 39% of the respondents think that the response time (to injury crashes) is poor, 18% consider it moderate, and 36% think it is quick. On the other hand, most police officials (80%) think their response time is quick or very quick.

According to most health authority respondents (75%), the system is somehow effective but needs some improvements. The majority of the police respondents (52%) also agreed on the need for improvement, though a big portion (45%) of the police respondents indicated effective EMS services.

3.10 Traffic Safety Stakeholders and Their Roles
Most experts (85%) admitted the possible role of other stakeholders in traffic safety issues. The Ministry of Education (or schools) was highly nominated as a strong stakeholder, for its potential role in providing traffic safety education among the children and youth. Municipalities, RTA, DOT and NTA can also be an important stakeholder. Their main responsibility will be planning better transport network, providing different modes of public transport, and designing safer roads. The Ministry of Information and Culture can also contribute to enhance people awareness of road safety issues through electronic and print media. The Ministry of Interior (Traffic Police) can play role by strict law enforcement, accident investigation, violation analysis and develop the behaviour of the road user. The Ministry of Health can provide post accident treatment; develop the skills of paramedics, and rehabilitation of the injured people. Other organization like mosques and social/sports clubs can increase people awareness on different road safety issues.

3.11 Opinion about Independent Institution
The experts were asked to give their opinion on the idea of establishing some independent institution, exclusively for traffic safety. This organization is envisioned to deal with all traffic safety issues and work closely with all the other stakeholders. Most of interviewees (81%) agreed with this idea.

3.12 Accident and Violation Data Analysis
Traffic police currently maintain some accident and violation records. These data are analyzed for decision-making purposes. Though most (59%) of the professional interviewees indicated that the gathered accident information is adequate to deal with traffic safety aspects, a good
portion (30%) have a totally different opinion. In another study (RTTSRC, 2009), 46% of the professionals indicated their satisfaction of the crash investigation data, 23% were not satisfied, and 31% were satisfied to some extent.

3.13 Driver’s Training and Licensing Process
In the interview, professionals show mixed opinion on the existing drivers training and licensing process. Only 35% think it is effective, 24% did not think the system is effective, and 41% think it is effective but needs some improvements.

3.14 Causes of Traffic Safety Problems
The main causes of traffic safety problems according to the users’ survey were road users’ behaviour (70.1%) and lack of awareness of road users (54.3%). Other significant causes were road-related (38.6%), vehicle-related (35.8%), inadequate training of the driver (35.2%) and law enforcement issues (27.9%).

Most experts (90%) indicated that road user behaviour is the main cause of traffic safety problem. Lack of awareness of road users (66.7%) was ranked as the second important cause. Other significant causes are law enforcement issues (49.2%), road-related (43.3%), inadequate training of drivers (38.3%), vehicle-related (30%), and inadequate coordination among traffic safety stakeholders (28.3%).

3.15 Improvements Needed For Traffic Safety
Both road users (60.3%) and experts (70.2%) suggest that campaigning is the major field that needs improvement. Strict traffic law and enforcement was the second most important field (52.5% users and 53.5% experts). The next most important one is road safety auditing programs (48.9% users and 54.4% experts). Other important fields are licensing system for new drivers, coordination among stakeholders, vehicle inspection programs, and data/information system.

4 PROPOSED SUGGESTIONS FOR IMPROVEMENTS
The study concludes the following suggestions to enhance the traffic safety status in the UAE
1. Establishment of a National Traffic Safety Authority (NTSA)
2. Educational programs in the schools
3. A continuous awareness campaign
4. Training on road safety related issues
5. Unified drivers’ training and licensing system in all the emirates
6. Rehabilitation programs for road user violations
7. Installation of demand based public transportation system
8. Implementation of a systematic Road Safety Auditing
9. Regular evaluation of traffic laws, rules and regulations
10. Strict law enforcement
11. Introduce more monitoring devices (ITS) for traffic violations
12. Introduce in-depth traffic accident and traffic violation research
13. Organize EMS system for traffic accident
14. Support future studies
15. Honor outstanding drivers
5 CONCLUSION
Road accidents in the UAE are one of the main causes of deaths and injuries, and represent a burden on future plans for social and economic developments. Bad driving attitude, lack of awareness and education, miscommunication and coordination among traffic safety stakeholders, enforcement of traffic laws and regulations, and inadequate data and research are affecting traffic safety potentials in the UAE.

The success of road safety in the country mainly relies on improving driving behaviour by education, continuous campaigning and installment of more monitoring devices. An exclusive independent organization for traffic safety can be also be promising for better coordination among stakeholders, responsibility, accountability and professional management of the whole sector. Finally, a strong political will and determination can lead to improvement of traffic safety in the UAE.

REFERENCES


Haddon J.W. (1980). The basic strategies from preventing damage from hazards of all kind, Hazard Prevention, 16: 8-11.


A Safety Audit Approach in Ranking Urban Road Crash Hotspots Using Analytical Hierarchy Process (AHP)  
(Case Study: Region 20 of Tehran)

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Abstract:  
Today existence of reliable crash data plays an important role in ranking hotspots and planning for road crash prevention programs. Yet, so many Road Crash data-based models have been developed for ranking hotspots. But crash data are rarely available in sufficient quantity or accuracy to justify the approaches in many countries and this problem prohibits even using ordinary crash data-based ranking models. To compensate this, the methodology presented in this study, aims to introduce a method for ranking high potential crash risk locations instead of actual high crash risk locations (locations with actual high crash history). The methodology used, involves defining a Safety Deficiency Value (SD-Value) to rank urban hotspots. SD-Value is defined as a number denoting the lack of safety in a distinct location and is measured by direct field inspection and measurement of crash contributing factors. The more the SD-Value is, the greater is the priority of location in the ranking. Road Crash contributing factors considered in this study have been Lighting, Marking and Signing Inadequacy, Not provided enough sight distances, Inadequate Drainage, Not Enough Pedestrian Facilities (if needed), Not Providing Safety Equipment (if needed), Existence of Effective Pavement Failures and Excessive Speeds of Vehicles. On the other hand, Road Crash contributing factors have different effects on lowering the safety level in crash hotspots. The importance weight of each factor has been calculated based on an analytical hierarchy approach (AHP). Moreover as the risk levels and the weights of contributing factors may be different in roadways and intersections, the hotspot type (the type of location) must also enter into the methodology. The total SD-Value of a location is calculated as the summation of the amount of each contributing factor times its respective weight of importance, regarding the location type. Finally to illustrate the methodology, an actual ranking problem has been followed as a case study for 7 hotspots of region 20 of Tehran, Iran. In this case study, the reported hotspots by the local officials, have been carefully inspected by a RSA team and contributed factors have been measured and based on the results, the ranking methodology has been applied.
1 INTRODUCTION

Worldwide, over 1.2 million people die each year on the world’s roads, and between 20 and 50 million suffer non-fatal injuries. In most regions of the world this epidemic of road traffic injuries is still increasing (World Health Organization, 2009). Without increased efforts and new initiatives, the total number of road traffic deaths worldwide and injuries has been forecasted to rise by some 65% between 2000 and 2020 (World Health Organization, 2004). Economically, the cost of road crash injuries is estimated at roughly 1% of gross national product (GNP) in low-income countries, 1.5% in middle-income countries and 2% in high-income countries. As well, on current trends, by 2020, road crash injury is likely to be the third leading cause of disability-adjusted life years lost (World Health Organization, 2004).

Recognizing the need for reducing the social and economic costs of road crashes, road agencies establish highway safety improvement programs. The approach commonly followed is referred to as accident hotspots remediation (Sayed, 1997). In such an approach, the phenomenon of accident clusters should be carefully recognized. There is considerable evidence showing that the identification and treatment of such sites with low-cost engineering remedial measures can be extremely cost-effective (Sayer, 1994).

Although, no universally accepted definition of road crash hotspots is given (Geurts and Wets 2003), the locations will in general be described as road crash hotspots. In broad terms, road crash hotspots programs involve the following functions (Sayed, 1997).

- Continuous monitoring of the road network to identify road crash hotspots;
- Analysis of the identified locations to find out what causes them to be crash hotspots;
- Given these locations and their problems, what countermeasures are effective to alleviate the problem?

The first function is usually referred to as the detection phase which defines the scope and size of the "safety problem". For a location to be identified as crash hotspots, it must exhibit a higher crash occurrence than an established "norm". Due to the random nature of crash occurrence, statistical techniques have been widely devised to ensure that only locations that have a "true" higher potential for crashes are identified as crash hotspot. These techniques are usually based on the hypothesis that crashes occur as random events with a known statistical distribution.

Virtisen (2002) describes that high-risk sites are targeted with the aim of improving safety on the road network through remedial treatment of these sites (Geurts and Wets 2003). Any achieved positive effect of safety measures at crash hotspots are denoted as the benefits of the implemented measures. Implementing safety measures is costly, but in theory, all measures generating a positive net-benefit should be applied. However, the restricted funding for hot spot safety work does put a limit to the number of sites that may be treated. Therefore, it is necessary to prioritize sites in order to utilize the limited funds as effectively as possible (Geurts and Wets, 2003).

There are many models used for identification and ranking crash hotspots, some of them are considered in literature review of this research in the next part. As it would be noted, almost all patterns of ranking crash hotspots are set based on crash data. Therefore existence of a reliable crash data plays an important role in road crash prevention programs. However, the problem may arise when dealing with insufficient or unreliable crash data, which may usually be occurred in developing countries.

Generally, despite the presence of traffic police at crash scenes in Iran, achieving the exact crash locations are often impossible due to some problems in data gathering. Of course efforts are underway to correct the police crash forms and to provide them with equipment for more exact
registration of crash data. On the other hand, there is no regular program for gathering environmental and traffic data in municipality of Tehran in order to apply them in ranking crash hotspots.

Because of large mentioned deficiencies of ranking crash hotspots based on crash data in Iran, the main purpose of this study is to develop a prioritization model based on field observation and investigation to rank them. In other words, an attempt is made in this research to identify and utilize the road related factors that pose high crash potentiality to the observed locations for ranking them. The method used to identify the importance of each crash contributing factor is AHP. This method will be described in methodology of this research.

2 RANKING CRASH HOTSPOTS

Some methods rank locations by crash rate (crashes per vehicle-kilometers or per entering vehicles), some use crash frequency (crashes per km-year or crashes per year) and some use a combination of the two (Hauer, 1996). More recently, the proportion of crash types considered susceptible to treatment is also used for ranking (Geurts and Wets 2003). Another dimension of diversity in practice is that rank may be determined by the magnitude (either of rate or frequency) or, as is more common, by the amount by which the rate or frequency exceed what is normal for such sites. According to The Bureau of Transport and Regional Economics of Australia (2001) locations are in general classified as crash hotspots after an assessment of the level of risk and the likelihood of a crash occurring at each location (Geurts and Wets 2003). At certain sites, the level of risk will be higher than the average level of same road elements.

As noted before, ranking crash hotspots are mostly based on crash datasets; but reliable crash data is hardly available to apply these approaches in the case of Tehran. Therefore this study’s aim is to present a methodology for ranking crash hotspots regardless of crash data. Up to now, limited similar investigations have been carried out. For example Mandloi and Gupta ranked crash hotspots using Geographical Information Systems (GIS) (Mandloi and Gupta 2003). Their model consists of prioritization of crash hotspots determined on a digitized map. They scored different locations based on the assessment of some parameters leading to crashes on each site. These parameters include road width, number of lanes, approximate traffic volume, type of road, drainage facilities, pavement surface condition, frequent vehicle types, presence of shoulders, edge obstructions, median barriers and radius of horizontal curves. Based on the site condition, a score is given to each parameter of the site and the final score of each site was calculated as the sum of the sub-scores of all parameters. This final score was used directly in ranking. In another research (Pirdavani, 2007), a method was proposed to identify and define relevant criteria implying crash hotspots’ characteristics, then a value was given to each criterion in order to develop a model to prioritize crash hotspots. To do this, the "Delphi" method was adopted and a prioritization model was developed, using "Multiple Criteria Decision Making" method (Pirdavani, 2007).

3 RESEARCH METHODOLOGY

The researchers generally define crashes as being a consequence of driver behavior that is not correctly matched with the demands of the road environment or to vehicle characteristics, or to both (Geurts and Wets 2003). The demands of the road environment vary due to factors such as traffic flow rates, geometric features of the road and type of road. Drivers normally adapt their performance level to the demands of the road system. A crash occurs when the driver's performance level is insufficient to meet the performance demands of the road environment.
Most of the time, driver capabilities exceed performance demands. Crash hotspots are points of peak performance demand. Engineering improvements in the road network lower performance demands on the driver while it increases the safety margin between the driver's performance level and the performance demands of the road environment, and reduces the probability of a crash (Geurts and Wets 2003). Based on the above discussion, this research comprises of the following steps:

- Identification of crash contributing factors (Road Environment Demand Factors)
- Finding the importance of each crash contributing factor in a quantitative basis and developing an index shows the safety deficiency in each site
- In-situ observation of distinct crash hotspots, measuring the crash contributing factors and finding the score (in term of safety deficiency value) in each location for final ranking.

Regarding the lack of the statistical resources, Roadway (or Intersection) safety deficiency (SD) denotes the lack of safety in a distinct location. In fact SD value is substituted with the crash related independent variables in ordinary crash predicting models. Though there are so many researches and experiences denoting the environmental contributing factors, resulting to the crashes (Pirdavani 2007 and Campbell 2003), to discover the exact factors affecting SD values, a survey also was conducted. Accordingly, important contributing factors distinguished as following1:

- Poor lighting
- Poor marking
- Poor signing
- Poor sight distances
- Poor drainage
- Poor pedestrian facilities
- Inadequate other needed equipment (sand barrels, guardrails, road studs, signals, etc if needed)
- Poor pavement condition
- Speed violence

The above factors show the homogeneity (the more the factor value, the worse the safety condition), as well as the independency. Each factor’s value should be computed based on field observation via a Road Safety Audit (RSA) procedure. Therefore to better setting the data, each factor must be quantified. Table 1 shows the contributing factors as well as how to measure them in a quantitative basis. As Table 1 shows, the amount of each factor varies between 0 and 100; while using medial amounts are also allowed. The upper limit denotes the worst condition, whilst the lowest amount represents the best.

---

1 Assuming “drivers select their speed based on the roadway conditions”, all contributing factors are in correlation with roadway and therefore using the auditing approach would be useful.
Table 1 – Quantifying Crash Contributing Factors

<table>
<thead>
<tr>
<th>Contributing Factor</th>
<th>Symbol</th>
<th>Measurement*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway links</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>$X_1$</td>
<td>0 if with proper lighting and 100 if without lighting</td>
</tr>
<tr>
<td>Marking</td>
<td>$X_2$</td>
<td>0 with good condition of marking and 100 with no marking</td>
</tr>
<tr>
<td>Signing</td>
<td>$X_3$</td>
<td>Percentage of improper signings, Damaged or without signs</td>
</tr>
<tr>
<td>Sight Distances</td>
<td>$X_4$</td>
<td>0 if provided and 100 if not provided</td>
</tr>
<tr>
<td>Drainage</td>
<td>$X_5$</td>
<td>0 if good condition and 100 if without</td>
</tr>
<tr>
<td>Pedestrian Facilities</td>
<td>$X_6$</td>
<td>$100 \times \left( \frac{\text{Length without Longitudinal Pedestrian Facilities}}{\text{Longitudinal walking length}} + \frac{\text{Required Crossing Facilities}}{\text{Total crossing facilities}} \right)$</td>
</tr>
<tr>
<td>Safety Equipment</td>
<td>$X_7$</td>
<td>Judgment on percentage of equipment loss</td>
</tr>
<tr>
<td>Pavement Failure</td>
<td>$X_8$</td>
<td>$\frac{\text{Affecting Area of Damaged pavements}}{\text{Total Pavement Area}}$</td>
</tr>
<tr>
<td>Speed</td>
<td>$X_9$</td>
<td>100 if hazardous and 0 if not hazardous²</td>
</tr>
</tbody>
</table>

* The amount between 0 and 100 is allowed according to the opinions of RSA team.

It should be stated that the importance of each contributing factor is not necessarily the same as the others and the proper weights must be considered. The total score of a site denoting the deficiency of safety in a distinct site (SD-value) is calculated as is shown in Equation 1.

$$SD = \sum_{i=1}^{9} \alpha_i X_i$$  \hspace{1cm} \text{Equation 1}$$

$SD =$ Safety Deficiency value

$X_i =$ The amount of $i^{th}$ crash contributing factor derived from Table 1 and field measurements

$\alpha_i =$ the weight of each $X_i$ derived from an AHP approach

The weights of the contributing factors ($\alpha_i$) are derived based on AHP in this study. This process is considered as one of the most popular analytical techniques for complex decision-making problems. Saaty developed AHP. This method which is found by Saaty decomposes a decision-making problem into a system of hierarchies of objectives, criteria, and alternatives. An AHP hierarchy can have as many levels as needed to fully characterize a particular decision situation.

² Hazard speed condition here, is defined as when most drivers exceeding the speed limit. Speed limit is the posted speed limit (if there is a speed limit sign) or the statutory speed limit (if there is no speed limit sign)
The main procedure of AHP technique is as follows:

Step 1: Determine the objective and the evaluation criteria and develop a hierarchical structure with a goal or objective at the top level, the criteria at the second level and the alternatives at the third level. (Number of levels may be different based on the extent of the problem)

Step 2: Determine the relative importance of different criteria with respect to the goal or objective.
- Construct a pair-wise comparison matrix using a scale of relative importance. The judgments are entered using the fundamental scale of AHP (Saaty 1980, 2000). To do this, suppose:

\[ w_i = \text{weight for criterion } i, \quad i=1,\ldots, n \text{ where } n = \text{number of criteria} \]

\[ a_{ij} = w_i / w_j = \text{the result of a pair-wise comparison between criterion } i \text{ as compared to criterion } j \]

\[ W = \text{matrix of pair-wise comparison values, } a_{ij} \]

Thus a set of pair-wise comparisons can be represented as the matrix below.

\[
\begin{bmatrix}
  x_1 & \ldots & x_3 & x_2 & x_1 \\
  x_1 & a_{1j} & \ldots & a_{13} & a_{12} & 1 \\
  x_2 & a_{2j} & \ldots & a_{23} & 1 & a_{21} \\
  \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\
  x_n & 1 & \ldots & a_{i3} & a_{i2} & a_{i1} \\
\end{bmatrix}
\]

- Find the relative normalized weight \( w_j \) of each criterion by (i) calculating the geometric mean of the i-th row, and (ii) normalizing the geometric means of rows in the comparison matrix.
- Determine the maximum Eigen value \( \lambda_{\text{max}} \) that is the average of matrix. Calculate the consistency index \( CI = (\lambda_{\text{max}} - n) / (n - 1) \). The smaller the value of CI, the smaller is the deviation from the consistency.
- Obtain the random index (RI) for the number of criteria used in decision making.
- Calculate the consistency ratio \( CR = CI / RI \). Usually, a CR of 0.1 or less is considered as acceptable, and it reflects an informed judgment attributable to the knowledge of the analyst regarding the problem under study.

Step 3: The next step is to compare the alternatives pair-wise with respect to how much better (i.e., more dominant) they are in satisfying each of the criteria, i.e., to ascertain how well each
alternative serves each criterion. If there is N number of alternatives, then there will be M number of N x N matrices of judgments, since there are M criteria. Construct pair-wise comparison matrices using a scale of relative importance. The judgments are entered using the fundamental scale of the AHP method (Saaty, 1980, 2000). The steps are the same as those suggested under main step 2.

Step 4: The next step is to obtain the overall or composite performance scores for the alternatives by multiplying the relative normalized weight ($w_j$) of each criterion (obtained in step 2) with its corresponding normalized weight value for each alternative (obtained in step 3), and summing over the criteria for each alternative.

Note that there are some software packages, such as Expert Choice which can do the AHP calculations and give the exact values. This Package has been used for determining the weights of contributing factors in this research.

4 APPLICATION

In literature, several approaches have been proposed to determine weights (Saaty, 1980, Hwang and Lin 1987, and Hwang and Yoon1981). The majority of them can be classified into either subjective approaches or objective approaches depending on the information provided. The objective approaches determine weights based on objective information (i.e. a decision matrix) and these weights may be different from one decision matrix to another. In other words, weights which are calculated from two decision matrices with the same criteria but different alternatives will be different (not unique). The subjective approaches select weights based on preference information of criteria given by the Decision Makers (DM). Amongst others, they include the eigenvector method (Saaty, 1977), the weighted least square method (Chu, Kalaba and Spingarn 1979) and the Delphi method (Hwang and Lin 1987). This research follows a subjective approach because the purpose of this study is to make one unique weight vector to be used in a comprehensive model.

The simple used hierarchy is illustrated in figure 1. The analysis is carried out for roadway links and intersections, individually.

Goal: Identifying more important accident contributing factors

![Fig1- Hierarchy for finding crash contributing factor weights](image)

To form the judgmental matrix, a survey was conducted and some experts were asked for pair-wise comparing the contributing factors. They also were asked to declare the relative importance weights (denoting the weights of dominant factor in pair-wise comparison in a 1 to 9 basis). The survey was carried out separately for roadway links and intersections. Tables 2 and 3 denote the judgmental matrices resulted from the survey, for roadway links and intersections respectively.
Table 2- Experts’ Comparison of Crash Contributing Factors on Roadway Links

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
<th>$X_9$</th>
</tr>
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<tbody>
<tr>
<td>$X_1$</td>
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</tr>
<tr>
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</tr>
<tr>
<td>$X_7$</td>
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<td>1</td>
<td>$\frac{1}{2}$</td>
<td>1</td>
<td>$\frac{1}{2}$</td>
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<td>$\frac{1}{2}$</td>
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<tr>
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<td>2</td>
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<td>$\frac{1}{3}$</td>
</tr>
<tr>
<td>$X_9$</td>
<td>4</td>
<td>4</td>
<td>4</td>
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<td>4</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>3</td>
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</tbody>
</table>

Table 3- Experts’ Comparison of Crash Contributing Factors at Intersections

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
<th>$X_9$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
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<td>2</td>
<td>2</td>
<td>$\frac{1}{3}$</td>
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<td>1</td>
<td>3</td>
<td>4</td>
<td>$\frac{1}{2}$</td>
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<tr>
<td>$X_2$</td>
<td>$\frac{1}{2}$</td>
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<td>1</td>
<td>$\frac{1}{5}$</td>
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<td>$\frac{1}{4}$</td>
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<tr>
<td>$X_3$</td>
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<td>1</td>
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<td>2</td>
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<tr>
<td>$X_4$</td>
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<td>3</td>
</tr>
<tr>
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<td>$\frac{1}{2}$</td>
<td>$\frac{1}{2}$</td>
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<td>$\frac{1}{2}$</td>
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<td>$\frac{1}{2}$</td>
<td>$\frac{1}{2}$</td>
<td>$\frac{1}{8}$</td>
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<td>$\frac{1}{5}$</td>
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<td>1</td>
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<td>3</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>1</td>
</tr>
</tbody>
</table>

To find the absolute weights of contributing factors with AHP approach, the Expert Choice Software was used. Using this software, weight values as well as the inconsistency ratio in the comparisons are shown in Table 4. As the Consistency Ratio (CR) values show, the comparisons have been consistent.
Table 4- Weights of Crash Contributing Factors

<table>
<thead>
<tr>
<th>Contributing factors</th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
<th>$X_9$</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway Links</td>
<td>0.119</td>
<td>0.069</td>
<td>0.055</td>
<td>0.118</td>
<td>0.049</td>
<td>0.127</td>
<td>0.055</td>
<td>0.094</td>
<td>0.314</td>
<td>0.03</td>
</tr>
<tr>
<td>Intersections</td>
<td>0.113</td>
<td>0.067</td>
<td>0.066</td>
<td>0.350</td>
<td>0.054</td>
<td>0.089</td>
<td>0.034</td>
<td>0.033</td>
<td>0.194</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Regarding weight vector and observed values of $X_i$ s measured by the RSA team at road crash hotspots, using equation 1, the safety deficiency values can be calculated. The values are directly used in ranking the locations.

5 CASE STUDY - DISTRICT 20 OF TEHRAN

Tehran metropolis, the capital of Iran, is divided by 22 districts. Each district is under the supervision of the local municipality. Traffic deputy in each district is responsible for managing traffic related issues (network analysis of traffic, road safety investigations, transit development, maintenance and rehabilitation, etc). On the other hand, Tehran Traffic and Transportation Organization (TTTO) is the superior part, supervising the 22 traffic deputies and control their activities. TTTO also cooperate with other departments of the municipality to provide the most efficient and safest traffic situation.

To well manage the crash hotspots in road networks, the deputies of districts were asked in this study to provide the TTTO with the list of crash hotspots. To provide the consistency in filling forms, high crash locations were defined as the sections or intersections, with annually 5 crashes or more. Table 5 shows the form used for gathering crash hotspots in each district. As Table 5 shows, the deputies were also asked to prioritize the high crash locations. This would help us to compare the research results with what was declared by the deputies. Consulting the traffic police, the deputies finally send the filled forms to TTTO.

Thereafter, an expert investigation was done for each spot reported by district’s traffic deputy. The aim of the investigation was to determine the causes the reported locations were set as crash hotspots. The investigation was carried out according to the principles of RSA. Investigations were done in a quantitative basis (i.e. practitioners were asked to calculate the amount of each $X_i$ according to Table 1). Knowing the values of crashes contributing factors and the weights of them, the SD values can be calculated for each reported location by Equation 1. In this section, the findings of the investigation on different reported locations of District 20 are addressed. SD values can be directly used to rank the crash hotspots.
The traffic deputy of district 20 reported 7 locations as road crash hotspots. These locations are listed in Table 6.

<table>
<thead>
<tr>
<th>Location</th>
<th>ID</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qom–Qeibi Intersection</td>
<td>P1</td>
<td>Intersection</td>
</tr>
<tr>
<td>Rajaee–13Aban Intersection</td>
<td>P2</td>
<td>Intersection</td>
</tr>
<tr>
<td>Namaz Square</td>
<td>P3</td>
<td>Intersection</td>
</tr>
<tr>
<td>Varamin T-junction</td>
<td>P4</td>
<td>Intersection</td>
</tr>
<tr>
<td>Qom–Iran Transfo Intersection</td>
<td>P5</td>
<td>Intersection</td>
</tr>
<tr>
<td>Alinavaz–Basij Intersection</td>
<td>P6</td>
<td>Intersection</td>
</tr>
<tr>
<td>Fadaee–Salman Farsi Intersection</td>
<td>P7</td>
<td>Intersection</td>
</tr>
</tbody>
</table>

After receiving reports, the RSA team investigated safety conditions of each location. In fact the team was to reply this question: What has made this location to be categorized as a crash hotspot? To reply explicitly, the RSA team measured the $X_i$ values according to Table 1 in each site. The results of the investigation are gathered in Table 7.
6 CONCLUSIONS AND RECOMMENDATIONS

As noted in this research, knowing the priority of crash hotspots is vital for scheduling the proper strategy to improve safety situation in such locations. Though there is no unique definition of crash hotspots and constant method for identification, almost all methodologies rely on road crash data for identification and prioritization of road crash locations. On the other hand, a proper road crash dataset has not ever established in some developing countries, though so many efforts are underway. Regardless of existence of a proper database, improving the condition of high crash locations is inevitable. To do this, a simple methodology was developed for ranking road crash hotspots without using road crash statistics. Key factors in dealing with this methodology are:

- The locations are to be ranked must be apparent exactly. Such locations may be listed according to police general reports, complements of living people, etc. The exact details of crashes would definitely help, though they don’t exist, sufficiently. Thus this method may be useful in locations with no exact crash data.
- Poor physical condition of the location may cause crashes. To find such condition, an RSA approach was used.
- This paper served 9 crash contributing factors. These factors were mainly selected based on the experts’ experiences as well as literature review. More factors (including the traffic volume, percentage of trucks, etc) may be investigated independently or in combination with other factors in more researches.
- To achieve more consistency in ranking conclusions, it is better to do an RSA by constant team at least in each district.
- Each relevant factor has not the same effect on crash occurrences. To find a proper weight of each factor, decision makers were asked about it.
- Estimate of funds needed to be spent in each location and the results in terms of decreasing road crash costs may be considered as a complementary approach in crashes’ investigation. Such an approach may be carried out in future investigations.

REFERENCES
Campbell et al. (2003). “Examination of Crash Contributing Factors Using National Crash Databases”, US DOT,
World Health Organization, (2009), “GLOBAL STATUS REPORT ON ROAD SAFETY, TIME FOR ACTION”.
ABSTRACT
Road safety is a relevant theme to study, due to the human as well as financial suffering caused by road crashes. To improve the level of road safety in a country, it is important to gain insight into this complex phenomenon. The development of a diverse set of road safety related indicators is valuable in this respect. Here, the concept of the road safety target hierarchy is used as a theoretical framework for presenting essential indicators of the safety management system. Special attention goes to final outcomes, intermediate outcomes, policy output and policy input. By listing indicators on the different levels of this hierarchy, not only final outcomes can be captured and monitored but also various aspects of road safety such as human behaviour, prevalent laws and economic background. This study aims at developing an appropriate indicator system for monitoring road safety in Europe. Possible indicators are formulated on each level of the hierarchy and subsequently evaluated using several criteria such as relevance and data availability. The final indicator set helps in offering a more complete picture of the road safety situation in a country or region and enables policymakers to better understand the underlying phenomena and take appropriate action at an early stage.

1 INTRODUCTION
Worldwide, an estimated 1.2 million people are killed in road crashes each year. The World Health Organization ranks road traffic injuries as 9th in the leading causes of death (WHO, 2009). In 25 countries of the European Union a total of almost 39,500 fatalities was registered in 2006, which is a decrease of 21.8% compared to the number in 2001 (SafetyNet, 2008). Despite the fact that positive results are achieved, the European Commission’s goal of halving the number of fatalities between 2001 and 2010 will probably not be achieved given the trend in the past.

Possibly, more complex problems need to be handled to further improve the road safety performance (e.g. Sivak and Tsimhoni, 2008). Therefore, it is important to gain insight into the underlying factors influencing the road safety level (often expressed by means of ‘final outcomes’) in a country or region. In this respect, we use the target hierarchy for road safety - originated in New Zealand (NRSC, 2000) and widely adopted in European projects such as SUNflower (Morsink et al., 2005) and SafetyNet (Vis, 2005) - which offers insight in the road safety processes that lead to casualties and social costs (Morsink et al., 2007). This by describing the road safety problem as a hierarchy consisting of five vertical levels from structure and culture (policy input) over safety measures and programmes (policy output), safety performance indicators (intermediate outcomes) and number of killed and injured (final outcomes) to social costs due to road unsafety (see: Figure 1).
Important road safety aspects can be identified throughout the pyramid (e.g. Morsink et al., 2007). At the horizontal level, each aspect can be specified in a disaggregated way such as per transport mode, road type or region. Furthermore, the pyramid contains a time dimension which allows the study of developments of factors over time (Morsink et al., 2007). In this paper, we concentrate on the components of the vertical dimension of the target hierarchy for road safety. Next, we briefly describe the vertical layers from top to bottom.

The social costs resulting from road unsafety are at the top of the target hierarchy for road safety. These are the costs that crashes impose on the community, on road users, emergency service providers and others (NRSC, 2000). The World Health Organization (2004) estimates the cost of road crashes and casualties to be 1 to 2% of the gross national product. In the European Union countries alone, the annual cost of road safety injury is approximated to exceed € 180 billion (WHO, 2004). Because some costs included in the estimation of the social costs are ambiguously measured in various countries (for example the quality of life loss), comparison of the social cost of crashes and casualties between countries or regions is limited (e.g. Elvik, 2000; Morsink et al., 2005; ETSC, 2007). Therefore, we do not address the quantification of the social costs in this paper. Nowadays, road safety is discussed in terms of final outcomes. Usually, the road safety level in a country or region is described and compared to that of others in terms of the number of casualties that need to be as low as possible (Morsink et al., 2007; Hermans, 2009). Because crash data do not provide insight in the safety problem areas of a country, we also take the underlying layers leading to crashes into account. Safety performance indicators (SPI’s) representing main risk factors (such as speed) are interesting since they are causally related to crashes or injuries and can predict safety levels before crashes happen (ETSC, 2001; Morsink et al., 2007). In the European SafetyNet project (Vis, 2005), safety performance indicators were formulated with respect to seven risk factors: alcohol and drugs, speed, protective systems, daytime running lights, vehicle, road infrastructure and trauma management. The SPI’s are influenced by the policy output layer that refers to the nature and content of national road safety plans, action programmes and safety related standards and legislation (Morsink et al., 2005). To achieve improvements in the SPI’s, it is possible that new laws or measures need to be created, enforcement need to be increased, etc. (e.g. Elvik, 2008). In order to come up with successful road safety actions, the structure and culture in a country or region has to be taken into account (policy input). Background differences between countries may imply that some measures will need to be customized in order to have the desired effect.

Figure 1: Target hierarchy for road safety (Morsink et al., 2005)
In this paper, we use the target hierarchy as a framework to develop an indicator system for monitoring road safety within Europe. By creating an indicator set including indicators on the final outcome, intermediate outcome, policy output and policy input level, the road safety situation within and between countries can be described and compared. Moreover, targets can be set on all levels of the target hierarchy. Nowadays, targets are often expressed in terms of a desired reduction in final outcomes. Nevertheless, it is interesting to set targets on the underlying levels as well because they allow closer management of the range of interventions by which goals set at a higher level can be reached (e.g. Elvik, 2008; ERSO, 2008).

When considering a diverse (final outcome, intermediate outcome, policy output and policy input) road safety indicator set, a country can obtain an enriched view on its current road safety situation, it can draw attention to main problems and help policymakers in setting targets and priorities (e.g. Hermans, 2009). The final indicator set generated from this study can be a first step to achieve the goal of a scientifically established set of safety indicators for the European Union (ETSC, 2001).

2 METHODOLOGY
To establish a harmonized set of road safety indicators using the target hierarchy for road safety as the theoretical framework, we go through several steps. First, we study each layer of the hierarchy in detail. Next, for each layer (except the ‘social cost’ layer) possible indicators are listed from international literature among which ETSC (2001); Sartre 3 (2004); Al Haji (2005); Morsink et al. (2005); Vis (2005); Morsink et al. (2007); Hermans (2009). Because a large number of potential indicators exist for each layer, implying excessive data collection efforts in a later stage, we will evaluate each indicator based on a set of criteria. As a result, a smaller (i.e. better manageable) and more valuable indicator set is obtained. In literature (e.g. Al Haji, 2005; Farchi et al., 2006; Hens et al., 2005; Ledoux et al., 2005; Litman, 2007 in: Hermans, 2009), several criteria defining a ‘good’ indicator can be found, e.g. understandable, clear definition, measurable, cost effective, reliable, stable.

After checking the possible conditions that an indicator should meet and taking the road safety context into account, eight selection criteria were identified, namely: the degree to which the indicator is relevant (and valid), measurable, understandable, has data available, is reliable, comparable (and coherent), specific and sensitive (Hermans, 2009). Below, we briefly describe each criterion by listing some questions that need to be asked to determine whether the indicator meets the criterion or not (Hermans, 2009):

- **RELEVANT/VALID**: is the indicator suitable for establishing targets? Does the indicator provide a good picture of the phenomenon that we want to measure?
- **MEASURABLE**: is the indicator quantifiable and measurable?
- **UNDERSTANDABLE**: is the indicator clearly defined? Does the indicator have a comprehensible and acceptable interpretation?
- **AVAILABLE DATA**: are data available for a large set of subjects (countries or regions in this case) within an acceptable term and at reasonable cost? Can the indicator be updated on a regular basis?
- **RELIABLE**: do the data come from a reliable source? Have the data been collected in a scientific way?
- **COMPARABLE/COHERENT**: is the indicator coherent over time (i.e., has the same definition, method, … been used) and over space (i.e., do the subjects apply the same definition, …)?
- **SPECIFIC**: does the indicator focus on a certain level? Is the indicator detailed enough?
- **SENSITIVE**: is the indicator capable of reflecting changes over time?
Based on these eight criteria, a distinction between best available indicators and best needed indicators can be made (European Commission, 2005). Best needed indicators can be seen as the most ideal indicators; they score best on five – not data related – criteria (relevance, measurability, interpretability, specificity and sensitivity) (Hermans, 2009). On the contrary, best available indicators take all eight listed criteria into account, including the availability of indicator data of an acceptable quality. Several European databases and reports (such as ERF, ETSC, Eurostat, IRTAD, OECD, SARTRE, …) are consulted in this respect. In the evaluation, indicators that meet the considered criterion are pointed by a ‘+’ sign; indicators that fall short by a ‘-’ sign. The sign ‘0’ refers to a score in between. Other possibilities are ‘0/+’; ‘-/0’; and ‘/-’ where the last symbol is used for rating reliability; in case no data are available, the degree of reliability is not applicable and not indicated (as a result only seven criteria are used then for identifying best available indicators). For each indicator scores are computed by quantifying these signs as follows: ‘+’= 1, ‘0/+’ = 0.5; ‘0’ = 0, ‘-/0’ = -0.5; ‘-’ = -1. Consequently, a set of best needed indicators and best available indicators will be created with respect to each layer. Because the maturity of indicators as well as the availability and quality of indicator data differ between the layers, some layers will be represented by a more elaborated set of indicators than others.

To overcome the current partial lack of indicator data and assure the creation and collection of necessary data for road safety policymaking in a longer time perspective, best available as well as best needed road safety indicators are identified. The overall best available road safety indicator set can be used in the short run for indicator analysis (e.g. Wilmots et al., 2009) while for the best needed indicator set the collection of road safety data is the first step to take (after agreement on the indicator set).

3 FINAL OUTCOME INDICATORS

In this section, we formulate and evaluate final outcome indicators. The process of evaluation will be illustrated for this layer whereas for the other layers, the same procedure is used but only the proposed best available and best needed indicator sets will be shown (due to space limitations). Of all layers in the target hierarchy for road safety, the final outcome layer has received most attention. Although the information on this layer is relevant, it only allows benchmarking at a macro level and does not reveal differences at a more detailed level (Morsink et al., 2007). Registered crash data say nothing about the processes that produce crashes and therefore do not indicate on which aspects an underperforming country should focus in order to improve its road safety level (ETSC, 2001; Hermans, 2009). In addition, the number of crashes or injuries is subject to random fluctuations. For these reasons, we create a monitoring system that includes indicators on all layers of the target hierarchy for road safety.

Comparisons based on ‘final outcomes’ can be limited, given differences in definitions and registration rates of injury crashes among countries (Morsink et al., 2005). To eliminate any problems related to biased underreporting of crashes with less serious outcomes and to avoid considerable differences in the definitions among countries, final outcome indicators usually refer to fatal crashes and fatalities (Morsink et al., 2007). To enable comparisons between countries or regions differing in size and mobility behavior, the number of fatalities is often expressed with respect to population (mortality rate), number of vehicles (fatality rate), or number of motorized vehicle kilometres or person kilometres (fatality risk) (Morsink et al., 2005; Morsink et al., 2007). Furthermore, final outcomes can be categorized (or disaggregated) in terms of transport mode, road user features (such as age), location and type of crash, etc.

Indicators related to final outcomes are listed from international literature (e.g. Morsink et al., 2007; Wegman et al., 2008), and subsequently evaluated using the eight selected criteria.
We concentrate on indicators that are related to the number of fatalities and are preferably expressed in terms of a relative measure.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Evaluation based on criteria</th>
<th>Selected indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td># fatalities / million inhabitants</td>
<td>Relevant</td>
<td>Measurable</td>
</tr>
<tr>
<td>Per age class</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td># fatalities / 100 registered motor vehicles</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td># fatalities / 100 million passenger kilometers</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Per road type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per age class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per transport mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per transport mode</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>% road fatalities out of total fatalities:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per road type</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Per age class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per transport mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of road fatalities resulting from crashes in which someone was drinking and driving</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>% of road users involved in fatal crashes impaired by alcohol and drugs</td>
<td>0/+</td>
<td>+</td>
</tr>
<tr>
<td>% of road fatalities due to excessive speed</td>
<td>0/+</td>
<td>+</td>
</tr>
<tr>
<td>% of car occupants fatalities not wearing a seat belt</td>
<td>0</td>
<td>+</td>
</tr>
</tbody>
</table>

- The number of fatalities is less subjected to differences in classifications and underreporting than the number of seriously or slightly injured.
- A change in this indicator might be due to a change in population rather than an actual change in road safety risk.
- The number of road fatalities per vehicle kilometers is the exposure to risk measure to prefer in the context of road safety.
- In some countries the number of road fatalities per vehicle kilometers traveled is not available, especially for the non-motorized kilometers traveled.
- The number of passenger kilometers traveled is often obtained in a different way. In some cases, it is based on inaccurate estimates.
- More countries have data on the amount of vehicle kilometers than on the amount of passenger kilometers traveled.
- A change in this indicator might be due to a change in the degree of reporting.
- The concept of “hospitalized” needs to be clearly defined and standardized.
- Centralized data are unavailable yet.
- In some countries only a small part is tested.
- A change in this indicator value might not be due to a better performance.
- Most countries do not report these data.

Figure 2: Best available and best needed final outcome indicator set

The evaluation process resulted in a best available indicator set consisting of the following indicators: the number of fatalities per age class per inhabitants in the particular age class, the share of road traffic fatalities per age class, road type or transport mode out of the total number of fatalities. The best needed indicator set for this layer is represented by the number of fatalities per 100 passenger kilometers per road type, age class or transport mode.
4 INTERMEDIATE OUTCOME INDICATORS

Safety performance indicators provide the link between the actions (‘policy output’) and the ‘final outcomes’ (e.g. Vis, 2005; Morsink et al., 2007; Tingvall et al., 2010). The European Transport Safety Council (2001) describes a safety performance indicator as “any measurement that is causally related to crashes or injuries and is used in addition to numbers of crashes or injuries, in order to indicate safety performance or understand the process that leads to crashes”. A main advantage of SPI’s is that they can point out the emergence of new problems at an early stage, before these problems show up in the form of crashes (ETSC, 2001). Because these intermediate outcomes are influenced by ‘policy output’ they are useful for monitoring and understanding the impact of road safety measures or programmes taken by policymaking authorities on a particular risk factor (ETSC, 2001).

In the European SafetyNet project (Vis, 2005), seven risk factors have been identified for which safety performance indicators are formulated. Some of these factors are related to behavioral characteristics (speed levels, the rate of drink driving, the use of seat belts), while other indicators refer to daytime running lights, the infrastructure, the vehicle or trauma management (ETSC, 2001; Vis, 2005). Various SPI’s can be quantified for these risk factors bearing in mind that the SPI should have a proven and well-documented relationship with the number of casualties and can be influenced by measures (ETSC, 2001; Tingvall et al., 2010).

For each risk factor, indicators were found in international literature such as Vis (2005); Morsink et al. (2007); Elvik (2008); Wegman et al. (2008); Hermans, 2009. Next, the best available and best needed indicator(s) for each risk factor are given.

<table>
<thead>
<tr>
<th>Risk domain</th>
<th>Best available indicator</th>
<th>Best needed indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol &amp; drugs</td>
<td>% of surveyed car drivers disrespecting the alcohol limit</td>
<td>% of road user population impaired by alcohol or drugs</td>
</tr>
<tr>
<td>Speed</td>
<td>% of surveyed car drivers exceeding the speed limit on ≠ road types</td>
<td>Average speed per road type and vehicle type, during daytime and at night</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variation in speed per road type and vehicle type</td>
</tr>
<tr>
<td>Protective systems</td>
<td>% of persons wearing a seat belt in the front seats of a car or van</td>
<td>% of persons wearing a seat belt in the front respectively rear seats of a vehicle (per vehicle and road type)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of persons &lt; 12 years (correctly) sitting in a child’s seat in the front or rear seat of a car</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Helmet wearing rate of cyclists, moped riders and motorcyclists</td>
</tr>
<tr>
<td>Daytime Running Lights</td>
<td>Existence of a law – fully or partially – obligating the use of daytime running lights</td>
<td>Usage rate of daytime running lights per road and vehicle type</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Age distribution of the vehicle fleet: % of vehicles ≤5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
<td>Age distribution of the vehicle fleet: % of vehicles ≤5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% cars rated 4 or 5 stars in EuroNCAP</td>
</tr>
<tr>
<td>Roads</td>
<td>Motorway density</td>
<td>% of road length with wide obstacle-free zone or roadside barrier</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% of road length with wide median or median barrier</td>
</tr>
<tr>
<td>Trauma management</td>
<td>% Gross Domestic Product spent on health care</td>
<td>Share of road casualties who died during hospitalization</td>
</tr>
</tbody>
</table>

Figure 3: Best available and best needed intermediate outcome indicator set
5 POLICY OUTPUT INDICATORS

As mentioned before, policy output refers to the nature and content of (national) road safety plans, action programmes and safety related standards and legislation (Morsink et al., 2005). The extent to which policymakers successfully organize safety policy in goals, strategies, and activities will be captured by means of indicators (Morsink et al., 2007). Good policy performance should result in a better safety performance and fewer final outcomes and lower social costs.

According to Elvik (2001) enforcement is an effective way to ensure better compliance with road traffic laws. Frequent police interventions that are unpredictable, well published and highly visible should raise the (objective and subjective) probability of being caught (ETSC, 2003). Moreover, the type and severity of sanctions play an important role. It is important to note that the quality of legislation and standards as well as the degree of compliance with them will determine the performance with respect to a particular risk factor (described by SPI’s). However, high-compliance with a low-quality law or standard will not improve safety outcomes and vice versa (Morsink et al., 2007). Furthermore, attitudes towards action programmes, laws, etc. need to be considered on the policy input layer to ensure compliance with these laws (Sartre, 2004; ERSO, 2006).

Road safety performance can also be improved by means of education with regard to road safety. Not only the basic skills on how to control a vehicle can be considered under ‘education’ but also the knowledge a person is taught by road safety education in primary school, by driver training programmes, by road safety campaigns, etc. (e.g. WHO, 2004). According to the World Health Organization (2004) informing and educating road users can improve knowledge about the rules of the road and the safety of vehicles. Further, education can influence attitudes towards interventions (see: policy input) and the behavior of road participants. For example, the risk of injury when not wearing a seat belt can be highlighted in educational programmes which can increase the seat belt wearing rate (WHO, 2009).

Furthermore, engineering measures can be taken to improve the safety of the road infrastructure and the vehicle fleet. These measures can be taken to reduce the crash risk (e.g. collision warning systems) or the crash severity (e.g. anti whiplash protection). Possible infrastructural measures are the separation of slow vulnerable traffic and other motorized traffic, the removal or protection of obstacles, etc (Elvik, 2008). Measures related to infrastructure can depend on a country’s background (see: policy input). Starting from a Sustainable Safety principle, the Netherlands have a clear categorization of roads build on principles such as functionality, homogeneity, recognizability and predictability (‘self-explaining’ roads) and forgiveness (Wegman et al., 2005).

Next, we present the best available and best needed indicator set for this layer of the target hierarchy for road safety. Possible policy output indicators, classifiable according to the 3 E’s (Enforcement, Engineering and Education) were found in literature (such as Sartre, 2004; Morsink et al., 2007; Elvik, 2008; Berg et al., 2009; ETSC, 2009). In this paper, we concentrate on measures formulated at the European level. However, it is possible that a country extends this particular indicator set from a more national point of view.
Figure 4: Best available and best needed policy output indicator set

6 POLICY INPUT INDICATORS
Policy input indicators refer to the policy context, such as emotions and public attitudes towards risk and safety, the organization of a country and its historical and cultural background (Morsink et al., 2005). These aspects need to be taken into account by policymakers when designing measures and setting up road safety programmes. For example, cultural differences in terms of the social acceptance of unwanted behavior such as drinking and driving can affect the success of a measure related to drunk driving.

So far, not much research has been carried out concerning this layer. Moreover, apart from restricting this layer to culture and structure (see Figure 1), a broader perspective is used. More specifically, external factors such as a country’s geographical features, demographic characteristics, etc. are also included under ‘policy input’ (e.g. Wegman et al., 2008; Wilmots et al., 2009). Although these aspects are not directly and solely related to road safety and are hard to influence within the scope of road safety alone they can contribute to a better understanding of the sources of road crashes and enable the application of more effective road safety policies (Eksler, 2008). Wilmots et al. (2009) found that besides SPI’s, four background indicators play a role in the explanation of the number of road fatalities per million inhabitants, namely ‘the gross domestic product’, ‘the average number of persons per household’, ‘the number of passenger cars per 1000 inhabitants’ and ‘the average number of kilometers travelled by a driver’. The last PIN report published by the European Transport Safety Council (ETSC, 2009) concludes that the economic recession and the high petrol prices have reduced the traffic volume in some European countries and partly resulted in a reduction in road fatalities in 2008. Also, the age distribution of the population can influence the road safety level since inexperienced drivers (often young drivers) have a higher crash risk and older drivers a higher injury risk. Below, we present the best available and best needed policy input indicator set (based on an evaluation of indicators found in international literature such as Sartre 3, 2004; Morsink et al., 2007; Wegman et al., 2008; Berg et al., 2009; Wilmots et al., 2009).
<table>
<thead>
<tr>
<th>Category</th>
<th>Best available indicator</th>
<th>Best needed indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Gross Domestic Product</td>
<td>Unemployment rate</td>
</tr>
<tr>
<td>Demographic</td>
<td>Age distribution of the population</td>
<td>Age distribution of the population</td>
</tr>
<tr>
<td></td>
<td>Average number of persons per household</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Number of passenger cars per 1000 inhabitants</td>
<td>Average number of passenger kilometers travelled per transport mode per age group</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Density of motorways</td>
<td>% road length per road type</td>
</tr>
<tr>
<td>Attitude</td>
<td>% surveyed drivers supporting more severe penalties for speeding or drink driving</td>
<td>% surveyed drivers supporting more severe penalties for speeding or drink driving</td>
</tr>
<tr>
<td>Characteristics of national safety programmes</td>
<td>The availability and ambition of national road safety targets</td>
<td>Systematical monitoring of the national road safety targets</td>
</tr>
</tbody>
</table>

Figure 5: Best available and best needed policy input indicator set

For this layer, we can conclude possible background and context indicators with regard to road safety are difficult to find. Furthermore, data availability is a problem and indicators are not easy to quantify. Future research concerning this layer can expose more suitable indicators.

7 CONCLUSIONS AND FUTURE RESEARCH
In this paper, we developed a best needed and best available indicator set for road safety as a first attempt in developing a harmonised indicator system for describing, comparing and monitoring road safety within Europe. The evaluation of a number of indicators on each level of the target hierarchy for road safety resulted in the following best available and best needed indicator set:
On the basis of literature and the assumption of causality between the layers of the target hierarchy for road safety, we assume that the indicators listed above have a strong relevance for road safety. As data issues currently limit the use of best needed indicators, best practices in terms of data collection need to be advocated. A manual developed at the European level, specifying the measuring of indicators and sampling designs (Hakkert & Gitelman, 2007) is a valuable tool contributing to uniform high-quality data collection in Europe. At this moment, first results can be obtained using the set of best available indicators. In particular, best-in-class countries or groups of similar countries can be identified, using an extensive and diverse set of final outcome, intermediate outcome, policy output and policy input indicators; each country could gain insight in its best and worst aspects; further, the interrelationships between indicators of a particular layer can be investigated (for example as tested by Tingvall et al. (2010) on the SPI’s layer) and the degree of correlation between indicators on different levels studied. The extent of the causal relationships between bottom layers and top layers is yet to be further explored (e.g. Morsink et al., 2005; Morsink et al., 2007; Wegman et al., 2008) to answer the question if and to which extent changes at the bottom affect the top layers of road safety. Moreover, in the future, targets could be assigned to each indicator and the evolution towards them monitored on a regular basis.

<table>
<thead>
<tr>
<th>Best available indicator set</th>
<th>Best needed indicator set</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Final outcomes</strong></td>
<td>3 fatalities / 100 million passenger kilometres per road type, age class or transport mode</td>
</tr>
<tr>
<td>% of road users who use alcohol or drugs</td>
<td>% of road users who use alcohol or drugs</td>
</tr>
<tr>
<td><strong>Intermediate outcomes</strong></td>
<td><strong>Policy output</strong></td>
</tr>
<tr>
<td>Alcohol &amp; drugs</td>
<td>% of road users who use alcohol or drugs</td>
</tr>
<tr>
<td>Speed</td>
<td>Average speed per road type and vehicle type, during daytime and at night</td>
</tr>
<tr>
<td>Prevalence systems</td>
<td>% of persons exceeding the speed limit on road type</td>
</tr>
<tr>
<td>Daytime Running Lights</td>
<td>% of persons exceeding the speed limit on road type</td>
</tr>
<tr>
<td>Vehicle</td>
<td>% of persons exceeding the speed limit on road type</td>
</tr>
<tr>
<td>% of surveyed car drivers exceeding the speed limit on road type</td>
<td>% of persons exceeding the speed limit on road type</td>
</tr>
<tr>
<td>% of persons wearing a seat belt in the front seat of a car</td>
<td>% of persons wearing a seat belt in the front seat of a car</td>
</tr>
<tr>
<td>% of persons wearing a seat belt in the front seat of a car</td>
<td>% of persons wearing a seat belt in the front seat of a car</td>
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<td>% of persons wearing a seat belt in the front seat of a car</td>
<td>% of persons wearing a seat belt in the front seat of a car</td>
</tr>
<tr>
<td>% of persons wearing a seat belt in the front seat of a car</td>
<td>% of persons wearing a seat belt in the front seat of a car</td>
</tr>
<tr>
<td>% of surveyed drivers who have been checked for alcohol over the last three years</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>Legal maximum speed limit per road type</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>% of the new cars (completely equipped with seat belt reminders)</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>% of annual road safety campaigns</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td><strong>Policy input</strong></td>
<td><strong>Policy output</strong></td>
</tr>
<tr>
<td>Gross Domestic Product</td>
<td>Number of persons annually checked with regard to a risk factor (use of alcohol/hard drugs, speed monitoring, protective systems, ...) per million licensed drivers per transport mode</td>
</tr>
<tr>
<td>Age distribution of the population</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>Average number of persons per household</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>Number of passenger cars per 1000 inhabitants</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>Density of motorways</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>% of surveyed drivers supporting more severe penalties for speeding or drink driving</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
<tr>
<td>The availability and evolution of national road safety targets</td>
<td>% of vehicles &lt;5 years, between 6-10 years, between 11-15 years and &gt;15 years in the total # of registered vehicles (per vehicle type)</td>
</tr>
</tbody>
</table>

**Figure 6: Best available and best needed indicator set**
REFERENCES


European Commission (2005). *Sustainable development indicators to monitor the implementation of the EU sustainable development strategy*. Commission of the European Communities: Brussels.


Sartre 3 consortium (2004). *European drivers and road risk*. INRETS.


A STATISTICAL ANALYSIS OF PERCEPTIVE FUNCTIONAL FAILURES – DRIVER BEHAVIOUR PRECENDING COLLISIONS

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Understanding specific traffic accident groups allows researchers and policy makers to develop solutions to failure sequences that commonly occur in the traffic environment. Functional failures are road user errors of perception, interpretation, planning or actioning and previous studies have identified factors that commonly occur within select accident groups but analysis has not been detailed due to limitations of the data. The role that perception plays in a driver’s actions is one of the most important aspects of traffic behavior. Failures during visual processing at the perceptive stage of driving can increase the probability that a crash will occur. Previous experimental studies have identified perceptive failures as a common factor in accident causation but until recently real-world accident data has not been sufficiently detailed for validation. New in-depth data from the UK On The Spot (OTS) project is now available to support the evaluation of these failures under real-world conditions.

The aims of this study were to determine the causal factors that most commonly occur with functional failures during the perceptive stage of driving. This study incorporated a factorial analysis research design. Cases with Perceptive stage failures that resulted in an accident were analyzed. These failures were classified as” Distraction” (538 cases), “Failure to look” (779 cases), “Looked but did not see” (706 cases) and “Inattention” (1659 cases). Descriptive statistics were used to identify significant factors related to the accident environment, vehicle and road user state for each accident group. Principle Component Analysis was used to identify patterns of factors for each main failure type. Seventeen scenarios were identified using this statistical methodology and are discussed.
1. Introduction
The World Health Organization estimates that road traffic injuries were the 11th leading cause of death worldwide, accounting for 2.1% of all deaths globally and for 23% of all injury deaths worldwide in 2006 (World Health Organization, 2006). In 2006 over 1.2 million people died as a result of road traffic collisions (on average 3242 fatalities per day) and 20 to 50 million people were injured or disabled in road collisions.

As the traffic environment becomes larger and more detailed in nature the type of accidents that occur are changing. Previous research has underlined some of the problems from previous decades but research into recent accidents is necessary to aid in the development of active and passive safety systems for present day and future vehicles.

As the traffic environment is complex and multi-layered it is necessary to use multiple methods in order to understand the errors/violations and contributory factors that lead to crash situations. In order to understand crashes it is necessary to put them into the context of underlying theoretical principles. Van Elslande and Puoqot (2007) defined human functional failures as factors differentiated from the human part of the system compared to those coming from the layout, traffic interaction and the vehicle. If we consider the traffic environment as a whole then a failure must occur within the system that will lead to the crash occurring.

The functional failure process is the process that occurs from the pre-crash event up until the critical error or violation is made during the crash situation. A failure can only apply to the road user. Roadway, vehicle, and environmental factors surrounding the road user can only contribute to that failure even though in some cases the main reason of the accident happening is one of these factors. Causal factors do not necessarily have to be present at every single stage of the functional failure, but usually there are at least two or more factors that have contributed to the crash occurring with one factor being primarily responsible.

In order to understand crashes we must understand the different phases that individuals go through preceding a crash. The perceptual stage that a road user is at during a crash situation allows investigators to determine which possible factor caused the crash. As the driving environment is extremely complex, the road user can only perceive a limited amount of information from the environment. The driver in turn needs to select the most relevant information from the traffic environment in order to make the necessary driving actions. After selecting the necessary information then an interpretation of the information needs to be made in order for a decision process to be made. These decisions are based on previous knowledge of different situations (Van Elslande and Pouquet, 2007).

The road user first perceives (stage 1) the information from the environment, then diagnoses (stage 2) the situation, anticipates (stage 3) how events will unfold, makes a decision (stage 4) and then performs an action (stage 5). The 5 stages can be viewed in a progressive manner, and are depicted in table 1.

Individuals have a limited capacity for processing information and as the demands on their capabilities increases visual stimuli must compete for attention especially in busy traffic areas and busy times of the day (Brown, 2005). This in turn causes the possibility of a perceptive failure to occur especially in situations where individuals have to react quickly (motorways, junctions) or where excessive speed is administered by the road user themselves. Human perceptual errors were identified as the main cause of road traffic accidents in 70% of cases as identified by two large studies on accident causation data (Treat et al, 1979 and Sabey et al 1975).
Table 1: Causation perceptual model from Van Elslande and Pouquet, 2007

**Perceptive stage:** Information detection function, search for information function

**Diagnosis stage:** Evaluation function of physical parameters, understanding function

**Prognosis stage:** Anticipation function of the situation evolution, prevision function of encountering a potential event

**Decisional stage:** Decision-taking function to undertake specific maneuver (error/violation)

**Psychomotor stage:** Performing action function

Mosedale (2004) found when reviewing the UK national accident data that as individual contributory factors to the main causative factor in an accident the “failed to look” factor was recorded in 16 percent of accidents, “Looked but did not see” was reported in 19 percent of accidents and “Inattention” was reported in 25 percent of accidents. Brown (2005) identified that “Looked but failed to see” accidents were most prominently occurring in junction accidents as definitely causative contributory factor (21 percent of crashes) compared to non junction situations (8 percent of crashes).

The aim of this study was to identify key traffic crash situations where perceptive failures occurred and identify the other factor(s) that contribute to a driver making these errors in relation to human, roadside, environment and infrastructure factors.

2. **Method**

2.1 **Design**

This study incorporated a factorial analysis research design. Data were acquired using in depth accident data methods on the spot by a group of accident researchers within an average time span of 20 minutes after an accident had occurred. All factors relating to the crash were obtained by the investigators and a subsample of perceptive stage failure accidents was selected from the dataset. The contributory factors that were identified by the accident investigators were then put into the relevant perceptive failure sub-group. The factors were grouped into four categories analyzing how the accidents were caused. These groups were Human, Vehicular, Infrastructural or Environmental factors. The factors were identified in accordance with whether they contributed to a crash happening and were related to the four Perceptive failure factors outlined above.

2.2 **Participants**

Accident data was collected by two separate groups in different areas. The Vehicle Safety Research Institute (VSRC) within the South Nottinghamshire area of East Midlands, England and the Transport Research Laboratory (TRL) covered the Slough, Reading, Henley on Thames and High Wycombe areas in the South East of England. Accident researchers responded to calls four times a week during 8 hour shifts, alternating hours for random data, to accidents that happened within this area. (Morris et al, 2005) The results presented in this paper are based on 4,004 crashes involving a total of 12,749 vehicles and 527 pedestrians. From this database cases with Perceptive stage failures,” Distraction” (538 cases), “Failure to look” (779 cases), “Looked but did not see” (706 cases) and “Inattention” (1659 cases), were analyzed.
2.3. Procedure
Accident researchers reported all relevant data in terms of the vehicle, environment, infrastructure and human participant in relation to the accident. They also deduced and reported causal factors that were related to the formation of the accident process.

2.4. Statistical Analysis
The goal of this study is to examine what the most relevant and common factor groupings and accident types were, when perceptive functional failures occur. The sample was analyzed by separating the different failure types (Distraction, Failure to look, Looked but did not see and Inattention) and identifying the key Human, Vehicular, Environmental and Infrastructure factors for each of the four failure types.

As the dataset consisted of more than 2,000 variables for each crash it was necessary to use an exploratory analysis tool to find significant factors. Principal component analysis was used to extract specific factors in the accident sample. Oblique rotations were used to perform the analyses. This analysis allows multiple factors to be linked to one corresponding outlining variable, allowing for correlations between these factors to be analyzed. The number of Principal Components considered depended on the factors that added up to 80% of the variance explained. Rather than using pre-conceived data chains to analyze the data this allowed for an exploratory analysis of the factors and linking them to particular perceptual stage failures, which in turn would allow for a comparison to previous research and findings. The main factors used for the analysis were chosen according to the causative factors that caused the accident, the failure that the road user made that directly caused the accident, the roadside variables (road type, speed limit, number of lanes) and the type of accident that occurred. The main extracted variables were then grouped in order to analyze which main accident types they caused.

As we aimed only to extract relevant factors we only analyzed the first four components for the distraction, looked but did not see and failed to look tables and six components for the inattention factor as these components added up to 50% of the variance. Variables loading higher than 0.4 were considered to have a significant correlation with the factor as a result of the large number of cases. For each table only variables that had a significant correlation within the component were used, the other variables were extracted in aid of clarity.

3. Results
In terms of road user and occupant injuries during the crash, serious and fatal outcomes were overrepresented in the “failure to look” (21.3%) group compared to the “Looked but did not see” (17.6%), “Inattention” (15.6%) and “Distraction” (11.6%) groups. Car to car collisions were underrepresented in “Looked but did not See” failure types. Car collisions with roadside features were overrepresented for “Inattention” failures. Lorry to car collisions were overrepresented for “Looked but did not see” failures. Pedestrian to cars and pedestrian to van collisions were overrepresented for both “Distraction” and “failed to look” failures. Younger pedestrians were overrepresented when “Inattention” was a functional failure and Male road users were overrepresented amongst “looked but did not see” failures.
3.1. Distraction
When distraction was identified as the main functional failure, four distinct components were found as a result of the analysis (table 3). The first component had a positive correlation with a three lane, motorway setting, where the road user was overtaking or lane changing, following too closely and failed to judge the other road users path which resulted in a rear end accident. This component had a negative correlation to failure to give way and a one lane unknown/private road. The second component had a positive correlation with a three lane straight road where the road user was trying an Overtaking or lane changing maneuver, the causative factors aggressive driving, being in a hurry, careless driving and panic behavior while driving were also correlated. Loss of control was the main failure while loss of control on a straight road was the accident type. The third component had a positive correlation with a failure to give way on an A class road where a failure to give way sign was present It had a negative correlation with pedestrians entering the carriageway and crossing the road. The fourth component had a positive correlation with misjudging speed at a give way junction.

Table 3: Correlations between PC’s and human factors for Distraction

<table>
<thead>
<tr>
<th>Factor type</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causative factors</td>
<td>Panic behaviour</td>
<td>0.252</td>
<td>0.53</td>
<td>0.136</td>
<td>-0.094</td>
</tr>
<tr>
<td></td>
<td>Carelessness, reckless or thoughtless</td>
<td>-0.099</td>
<td>0.441</td>
<td>0.198</td>
<td>0.135</td>
</tr>
<tr>
<td></td>
<td>In a hurry</td>
<td>-0.179</td>
<td>0.416</td>
<td>0.185</td>
<td>0.147</td>
</tr>
<tr>
<td></td>
<td>Failure to judge others persons path</td>
<td>0.401</td>
<td>-0.290</td>
<td>0.060</td>
<td>0.470</td>
</tr>
<tr>
<td></td>
<td>Following too close</td>
<td>0.431</td>
<td>-0.242</td>
<td>-0.019</td>
<td>0.242</td>
</tr>
<tr>
<td></td>
<td>Aggressive driving</td>
<td>0.204</td>
<td>0.585</td>
<td>0.127</td>
<td>0.300</td>
</tr>
<tr>
<td>Accident type</td>
<td>Overtaking or lane changing</td>
<td>0.518</td>
<td>0.450</td>
<td>0.079</td>
<td>0.090</td>
</tr>
<tr>
<td></td>
<td>Loss of control on Straight Road</td>
<td>0.176</td>
<td>0.496</td>
<td>0.096</td>
<td>-0.344</td>
</tr>
<tr>
<td>Display of site variables</td>
<td>thirty mile per hour speed limit</td>
<td>-0.670</td>
<td>0.163</td>
<td>-0.227</td>
<td>0.220</td>
</tr>
<tr>
<td></td>
<td>seventy mile per hour speed limit</td>
<td>0.794</td>
<td>0.177</td>
<td>-0.041</td>
<td>-0.006</td>
</tr>
<tr>
<td></td>
<td>Give way instructions</td>
<td>-0.256</td>
<td>-0.101</td>
<td>0.411</td>
<td>0.461</td>
</tr>
<tr>
<td></td>
<td>No active yield sign</td>
<td>0.312</td>
<td>0.072</td>
<td>-0.473</td>
<td>-0.284</td>
</tr>
<tr>
<td>Road type</td>
<td>A class road</td>
<td>-0.085</td>
<td>-0.144</td>
<td>0.405</td>
<td>-0.477</td>
</tr>
<tr>
<td></td>
<td>Motorway</td>
<td>0.776</td>
<td>0.106</td>
<td>-0.098</td>
<td>0.254</td>
</tr>
<tr>
<td></td>
<td>Unknown road</td>
<td>-0.453</td>
<td>0.062</td>
<td>-0.398</td>
<td>0.332</td>
</tr>
<tr>
<td></td>
<td>one lane road</td>
<td>-0.666</td>
<td>-0.018</td>
<td>0.074</td>
<td>0.153</td>
</tr>
<tr>
<td></td>
<td>three lane road</td>
<td>0.537</td>
<td>0.445</td>
<td>0.051</td>
<td>0.127</td>
</tr>
<tr>
<td>Failure type</td>
<td>failed to avoid object</td>
<td>0.402</td>
<td>-0.670</td>
<td>-0.069</td>
<td>0.232</td>
</tr>
<tr>
<td></td>
<td>failed to give way</td>
<td>-0.435</td>
<td>0.060</td>
<td>0.405</td>
<td>0.368</td>
</tr>
<tr>
<td></td>
<td>loss of control</td>
<td>0.217</td>
<td>0.466</td>
<td>0.086</td>
<td>-0.305</td>
</tr>
<tr>
<td></td>
<td>pedestrian entered carriageway</td>
<td>-0.295</td>
<td>0.149</td>
<td>-0.760</td>
<td>-0.037</td>
</tr>
</tbody>
</table>

3.2. Failure to look
Four components had significant correlations which can be seen in table 4. The first component had a positive correlation with a rear end accident, on a three lane motorway setting, where the road user failed to avoid the other road user and a failed to judge the other road users speed. It had a negative correlation with a thirty mile per hour situation where a pedestrian entered the carriageway and pedestrian crossed the road (causative factor). The second component had a positive correlation with factors failure to give way where a give way instruction was present, and a negative correlation with crossing from behind parked vehicle, pedestrian entered the carriageway and pedestrian crossing the road as a causative factor. The third component had a positive correlation with a two lane traffic light controlled A class road with a 40mph setting with a failure to stop. The fourth component had a positive correlation with poor turn and overtaking or lane changing and a negative correlation with rear end accident.

Table 4: Correlations between PC’s and Human factors for Failure to look

<table>
<thead>
<tr>
<th>Factor type</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causative factors</td>
<td>Failure to judge others persons path</td>
<td>0.451</td>
<td>-0.079</td>
<td>-0.032</td>
<td>0.086</td>
</tr>
<tr>
<td></td>
<td>Cross from behind parked car</td>
<td>-0.330</td>
<td>-0.418</td>
<td>0.069</td>
<td>-0.090</td>
</tr>
<tr>
<td></td>
<td>Excessive speed</td>
<td>-0.129</td>
<td>0.303</td>
<td>0.065</td>
<td>0.099</td>
</tr>
<tr>
<td></td>
<td>Following too close</td>
<td>0.613</td>
<td>-0.136</td>
<td>-0.211</td>
<td>-0.362</td>
</tr>
<tr>
<td></td>
<td>Inexperience of driving</td>
<td>-0.150</td>
<td>0.098</td>
<td>0.071</td>
<td>0.162</td>
</tr>
<tr>
<td></td>
<td>Aggressive driving</td>
<td>-0.072</td>
<td>0.364</td>
<td>0.088</td>
<td>0.204</td>
</tr>
<tr>
<td>Accident type</td>
<td>Pedestrians crossing road</td>
<td>-0.448</td>
<td>-0.633</td>
<td>0.171</td>
<td>-0.162</td>
</tr>
<tr>
<td></td>
<td>Overtaking or lane changing</td>
<td>0.356</td>
<td>-0.291</td>
<td>-0.156</td>
<td>0.535</td>
</tr>
<tr>
<td></td>
<td>Rear end</td>
<td>0.641</td>
<td>-0.090</td>
<td>-0.217</td>
<td>-0.471</td>
</tr>
<tr>
<td>Display of site variables</td>
<td>Give way instructions</td>
<td>0.050</td>
<td>0.568</td>
<td>-0.235</td>
<td>-0.338</td>
</tr>
<tr>
<td></td>
<td>No active yield sign</td>
<td>-0.165</td>
<td>-0.623</td>
<td>-0.266</td>
<td>0.332</td>
</tr>
<tr>
<td></td>
<td>Sixty mile per hour speed limit</td>
<td>0.229</td>
<td>0.101</td>
<td>-0.235</td>
<td>-0.099</td>
</tr>
<tr>
<td></td>
<td>Thirty mile per hour speed limit</td>
<td>-0.638</td>
<td>-0.061</td>
<td>0.002</td>
<td>-0.181</td>
</tr>
<tr>
<td></td>
<td>Forty mile per hour speed limit</td>
<td>0.243</td>
<td>0.188</td>
<td>0.413</td>
<td>0.212</td>
</tr>
<tr>
<td></td>
<td>Traffic light control</td>
<td>0.174</td>
<td>0.167</td>
<td>0.671</td>
<td>-0.053</td>
</tr>
<tr>
<td>Road type</td>
<td>A class road</td>
<td>0.259</td>
<td>0.064</td>
<td>0.575</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>B class road</td>
<td>-0.040</td>
<td>0.173</td>
<td>-0.203</td>
<td>0.059</td>
</tr>
<tr>
<td></td>
<td>Motorway</td>
<td>0.536</td>
<td>-0.287</td>
<td>-0.312</td>
<td>0.218</td>
</tr>
<tr>
<td></td>
<td>Unknown road</td>
<td>-0.486</td>
<td>0.005</td>
<td>-0.295</td>
<td>-0.197</td>
</tr>
<tr>
<td></td>
<td>One lane roadway</td>
<td>-0.470</td>
<td>0.372</td>
<td>-0.329</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>Two lane roadway</td>
<td>0.341</td>
<td>-0.105</td>
<td>0.462</td>
<td>-0.170</td>
</tr>
<tr>
<td></td>
<td>Three lane roadway</td>
<td>0.513</td>
<td>-0.151</td>
<td>-0.071</td>
<td>0.055</td>
</tr>
<tr>
<td>Failure type</td>
<td>Failed to avoid object</td>
<td>0.530</td>
<td>-0.123</td>
<td>-0.358</td>
<td>-0.227</td>
</tr>
<tr>
<td></td>
<td>Poor turn</td>
<td>0.198</td>
<td>-0.066</td>
<td>0.099</td>
<td>0.677</td>
</tr>
<tr>
<td></td>
<td>Failed to stop</td>
<td>0.311</td>
<td>0.099</td>
<td>0.432</td>
<td>-0.342</td>
</tr>
<tr>
<td></td>
<td>Failed to give way</td>
<td>-0.277</td>
<td>0.691</td>
<td>-0.206</td>
<td>-0.043</td>
</tr>
<tr>
<td></td>
<td>Pedestrian entered carriageway</td>
<td>-0.478</td>
<td>-0.677</td>
<td>0.130</td>
<td>-0.179</td>
</tr>
</tbody>
</table>

3.3. Looked but did not see

Three components had significant correlations which can be seen in table 5. The first component had overtaking or lane changing as the type of accident, with a three lane 70 mile per hour motorway, where there was a no active yield signs and the road user had there view obscured by the vehicles window and failed to avoid the object. This component had a negative correlation with a one lane failed to give way scenario, on a 30mph road and a give way sign. The second component was a situation on a 40mph a class road, where the road user was doing excessive speed for the conditions, was in a
hurry and acted in a careless manner and failed to stop. This component had a negative correlation with a thirty mph unknown road. The third component had a positive correlation with a rear end crash where excessive speed and poor lighting was a major factor, there were no roadside attributes positively correlated to this component and failure to give way was negatively correlated. The fourth component did not have significant factors for analysis.

Table 5: Correlations between PC’s and Human factors for Looked But did not see

<table>
<thead>
<tr>
<th>Factor type</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causative factors</td>
<td>Careless, reckless or thoughtless</td>
<td>0.021</td>
<td>0.449</td>
<td>0.114</td>
<td>0.157</td>
</tr>
<tr>
<td></td>
<td>In a hurry</td>
<td>-0.137</td>
<td>0.525</td>
<td>0.048</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>Excessive speed</td>
<td>-0.004</td>
<td>0.514</td>
<td>0.472</td>
<td>0.256</td>
</tr>
<tr>
<td></td>
<td>Poor or no street lighting at site</td>
<td>-0.010</td>
<td>0.246</td>
<td>0.566</td>
<td>0.231</td>
</tr>
<tr>
<td></td>
<td>View obscured from window</td>
<td>0.448</td>
<td>-0.145</td>
<td>-0.219</td>
<td>0.312</td>
</tr>
<tr>
<td></td>
<td>Glare from sun</td>
<td>-0.258</td>
<td>-0.014</td>
<td>-0.089</td>
<td>0.098</td>
</tr>
<tr>
<td>Accident type</td>
<td>Overtaking or lane changing</td>
<td>0.713</td>
<td>-0.057</td>
<td>-0.193</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>Rear end</td>
<td>0.178</td>
<td>0.247</td>
<td>0.428</td>
<td>-0.063</td>
</tr>
<tr>
<td>Display of site variables</td>
<td>seventy mile per hour speed limit</td>
<td>0.782</td>
<td>-0.080</td>
<td>-0.207</td>
<td>0.203</td>
</tr>
<tr>
<td></td>
<td>thirty mile per hour speed limit</td>
<td>-0.504</td>
<td>-0.461</td>
<td>0.232</td>
<td>-0.098</td>
</tr>
<tr>
<td></td>
<td>Forty mile per hour speed limit</td>
<td>0.028</td>
<td>0.445</td>
<td>-0.235</td>
<td>-0.286</td>
</tr>
<tr>
<td></td>
<td>Give way instructions</td>
<td>-0.494</td>
<td>0.180</td>
<td>-0.391</td>
<td>0.415</td>
</tr>
<tr>
<td></td>
<td>No active yield sign</td>
<td>0.476</td>
<td>-0.244</td>
<td>0.353</td>
<td>-0.270</td>
</tr>
<tr>
<td>Road type</td>
<td>A class road</td>
<td>-0.007</td>
<td>0.537</td>
<td>-0.277</td>
<td>-0.500</td>
</tr>
<tr>
<td></td>
<td>B class road</td>
<td>-0.290</td>
<td>0.050</td>
<td>0.171</td>
<td>0.422</td>
</tr>
<tr>
<td></td>
<td>Motorway</td>
<td>0.782</td>
<td>-0.266</td>
<td>-0.181</td>
<td>0.359</td>
</tr>
<tr>
<td></td>
<td>Unknown road</td>
<td>-0.316</td>
<td>-0.495</td>
<td>0.321</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>one lane roadway</td>
<td>-0.723</td>
<td>-0.119</td>
<td>0.322</td>
<td>0.181</td>
</tr>
<tr>
<td></td>
<td>two lane roadway</td>
<td>0.238</td>
<td>0.311</td>
<td>-0.252</td>
<td>-0.512</td>
</tr>
<tr>
<td></td>
<td>three lane way</td>
<td>0.648</td>
<td>-0.115</td>
<td>-0.126</td>
<td>0.317</td>
</tr>
<tr>
<td>Failure type</td>
<td>failed to avoid object</td>
<td>0.527</td>
<td>-0.059</td>
<td>0.285</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td>failed to stop</td>
<td>0.089</td>
<td>0.459</td>
<td>0.164</td>
<td>0.068</td>
</tr>
<tr>
<td></td>
<td>failed to give way</td>
<td>-0.650</td>
<td>-0.145</td>
<td>-0.440</td>
<td>0.172</td>
</tr>
</tbody>
</table>

3.4 Inattention

Six components were analyzed as can be seen in table 6. The first PC had a positive correlation with a rear end accident, in a three lane 70mph motorway setting, where the road user failed to avoid the object road user as they were following too closely. This component had a negative correlation with a failure to give way on a one lane private road, with a 30 miles per hour speed limit. The second component had positive correlations with a loss of control on straight road accident on a motorway where a pedestrian entered the carriageway and the road user lost control. The third component did not have enough correlations to interpret. The fourth PC had a positive correlation with a head on accident where there was a sixty mile one lane road and the road user lost control. This PC had a negative correlation with pedestrians entering the carriageway and crossing the road. The fifth component had a positive correlation with Pedestrians entering the carriageway when the road user was in a hurry with pedestrians crossing the road a causative factor and a negative correlation with a failure to give way. The sixth component had a positive correlation with an overtaking maneuver on a crossing where a vehicle was turning with a poor turn being the causative maneuver and a failure to stop being negatively correlated.
Table 6. Correlations between PC`s and human factors for Inattention

<table>
<thead>
<tr>
<th>Factor type</th>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causative factors</td>
<td>In a hurry</td>
<td>-0.352</td>
<td>-0.068</td>
<td>-0.029</td>
<td>0.032</td>
<td>0.429</td>
<td>0.142</td>
</tr>
<tr>
<td></td>
<td>Failure to judge others path</td>
<td>0.271</td>
<td>-0.389</td>
<td>0.197</td>
<td>-0.051</td>
<td>0.017</td>
<td>0.431</td>
</tr>
<tr>
<td></td>
<td>Following too close</td>
<td>0.591</td>
<td>-0.228</td>
<td>0.371</td>
<td>-0.036</td>
<td>-0.151</td>
<td>-0.042</td>
</tr>
<tr>
<td>Accident type</td>
<td>Overtaking or lane changing</td>
<td>0.118</td>
<td>0.058</td>
<td>-0.263</td>
<td>0.102</td>
<td>0.323</td>
<td>0.440</td>
</tr>
<tr>
<td></td>
<td>Rear end</td>
<td>0.647</td>
<td>-0.383</td>
<td>0.338</td>
<td>-0.092</td>
<td>0.012</td>
<td>-0.028</td>
</tr>
<tr>
<td></td>
<td>Pedestrians crossing road</td>
<td>-0.331</td>
<td>0.386</td>
<td>0.359</td>
<td>0.0413</td>
<td>0.452</td>
<td>-0.115</td>
</tr>
<tr>
<td></td>
<td>Loss of control on straight road</td>
<td>0.134</td>
<td>0.480</td>
<td>-0.328</td>
<td>0.320</td>
<td>-0.028</td>
<td>-0.228</td>
</tr>
<tr>
<td></td>
<td>Crossing (vehicle turning)</td>
<td>-0.194</td>
<td>-0.054</td>
<td>-0.195</td>
<td>-0.017</td>
<td>-0.112</td>
<td>0.427</td>
</tr>
<tr>
<td></td>
<td>Head on</td>
<td>-0.130</td>
<td>-0.032</td>
<td>0.085</td>
<td>0.460</td>
<td>0.077</td>
<td>-0.196</td>
</tr>
<tr>
<td>Display of site variables</td>
<td>seventy mile per hour speed limit</td>
<td>0.779</td>
<td>0.304</td>
<td>-0.223</td>
<td>-0.134</td>
<td>0.018</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>thirty mile per hour speed limit</td>
<td>-0.653</td>
<td>0.165</td>
<td>0.195</td>
<td>-0.181</td>
<td>-0.263</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>sixty mile per hour speed limit</td>
<td>-0.041</td>
<td>-0.284</td>
<td>0.183</td>
<td>0.570</td>
<td>0.276</td>
<td>-0.103</td>
</tr>
<tr>
<td></td>
<td>No active yield sign</td>
<td>0.353</td>
<td>0.383</td>
<td>0.470</td>
<td>0.339</td>
<td>0.196</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>traffic light control</td>
<td>-0.217</td>
<td>-0.371</td>
<td>-0.460</td>
<td>-0.329</td>
<td>-0.054</td>
<td>-0.19</td>
</tr>
<tr>
<td></td>
<td>Aclassroad</td>
<td>-0.124</td>
<td>-0.636</td>
<td>-0.209</td>
<td>0.038</td>
<td>0.272</td>
<td>-0.200</td>
</tr>
<tr>
<td>Road type</td>
<td>Motorway</td>
<td>0.776</td>
<td>0.402</td>
<td>-0.098</td>
<td>-0.075</td>
<td>-0.096</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>private road</td>
<td>-0.511</td>
<td>0.374</td>
<td>0.319</td>
<td>-0.104</td>
<td>-0.248</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>one lane roadway</td>
<td>-0.551</td>
<td>-0.184</td>
<td>0.348</td>
<td>0.456</td>
<td>0.247</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>three lane roadway</td>
<td>0.574</td>
<td>0.351</td>
<td>-0.172</td>
<td>-0.089</td>
<td>-0.178</td>
<td>-0.047</td>
</tr>
<tr>
<td>Failure type</td>
<td>failed to avoid object</td>
<td>0.477</td>
<td>-0.270</td>
<td>0.451</td>
<td>-0.017</td>
<td>-0.142</td>
<td>0.159</td>
</tr>
<tr>
<td></td>
<td>poor turn</td>
<td>-0.050</td>
<td>0.071</td>
<td>-0.130</td>
<td>-0.020</td>
<td>0.073</td>
<td>0.557</td>
</tr>
<tr>
<td></td>
<td>failed to stop</td>
<td>0.110</td>
<td>-0.350</td>
<td>-0.159</td>
<td>-0.092</td>
<td>0.149</td>
<td>-0.441</td>
</tr>
<tr>
<td></td>
<td>failed to give away</td>
<td>-0.410</td>
<td>-0.070</td>
<td>-0.218</td>
<td>-0.125</td>
<td>-0.471</td>
<td>0.210</td>
</tr>
<tr>
<td></td>
<td>loss of control</td>
<td>0.061</td>
<td>0.491</td>
<td>-0.352</td>
<td>0.422</td>
<td>0.007</td>
<td>-0.296</td>
</tr>
<tr>
<td></td>
<td>pedestrian entered carriageway</td>
<td>-0.358</td>
<td>0.406</td>
<td>0.378</td>
<td>-0.411</td>
<td>0.455</td>
<td>-0.100</td>
</tr>
</tbody>
</table>

4. Discussion

We found that certain situations within the traffic environment commonly lead to Perceptive Failure accidents occurring. Five of the components involved vehicles in a motorway situation, in three of these the main accident type was a rear end accident, where the road user was not keeping an appropriate distance with the speed that the vehicle was travelling at. Two of the rear end situations with “distraction” and “failed to look” as the perceptive failures the road user failed to correctly interpret the path and speed that the other road user was taking. For the “Inattention” perceptive failure situation there was a failure to avoid the other road user. The other two factors within a motorway setting which were positively correlated were an overtaking or lane changing maneuver within a “looked but did not see” situation where the view was obscured by the vehicles window and the road user failed to avoid the object while in the Inattention situation. The road user lost control on the straight road as a result of a pedestrian entering the road. Excessive speed for the activity was also a causative factor within a “looked but failed to see” situation where the driver was reckless and in a hurry on a 40 mile per hour speed limit road and this caused a failure to stop. At the higher speed scenarios it becomes more difficult for road users to make any adaptive maneuvers to the conflict situation once it arises. Adaptive cruise control could be used to both controls for other vehicles driving on the motorways and also for road users to obey the posted speed limits, especially valuable in situations where road users have high velocity crashes. Lane departure warning systems and collision warning systems could also help eradicate some of these scenarios as they can bring
an individual’s attention to the conflict situation possibly in time for a reactionary maneuver to be made though still not sufficient in certain situations.

The “Looked but failed to see” accidents for the second component the road user was are similar to those identified by Koustani et al (2008) where individuals collided at junctions that they regularly used in a lower speed setting, both the second and fourth components correlated with a lower speed situation. The second component also had a positive correlation with excessive speed for the road and was in a hurry where road users were surprised by another road user’s action and failed to stop. Two of the components found within this study (overtaking on a motorway and the rear end accident) were not reported in the other study though this may be a result of the sample size being larger for this study (706 cases to 77 cases) and different types of roadside infrastructure. The Looked but did not see analysis had the only vehicular (window obscuring the road users view) and Infrastructural (poor or no street lighting) causative factors within the analysis. This could be due to the different visual search patterns between the other three factor types and Looked but did not see accidents, as Looked but did not see accidents relate more closely to visual search limits (Koustani et al, 2008) while the other three failures are related to the road users inability to correctly use there visual search patterns.

The “failure to look” category had the highest level of fatal accidents in the current study this can possibly be attributed to the first two components being related to loss of control accidents and overtaking accidents which have a higher possibility of injury compared to rear end accidents which were in the first component for both the Distraction and Inattention analysis. Individuals within younger age groups had a positive correlation to Inattention and Looked but did not see accidents as individual factors, but did not have a significant correlation when included as Principal component factors. Older drivers were also overrepresented within the distraction scenarios but also did not have a significant correlation when included as a Principal component factor. The first component for failure to look can explain the higher representation of pedestrian accidents within this group compared to the other groups, as this was the only scenario that occurred on a single lane road with a thirty mile per hour speed limit though pedestrian placement did not have a significant positive correlation on the component.

There are certain limitations in this study. Due to the large number of variables and the large sample size a lower significance level (0.4) was used in order to analyze the components. This could cause overestimation of the components though as the aim was to conduct an exploratory analysis of factors that lead to accident situation with perceptive functional failures this analysis allowed for this. As the dataset was larger most of the analysis concentrated on car to car crashes as a more in depth analysis is necessary for analysis of different accidents.

This study identified certain traffic roadside situations and human factors that commonly occur in perceptive stage failures. We propose that future studies will concentrate on identifying specific road side characteristics where these accidents occur. Furthermore a further analysis considering all of the available national and international data could be carried out to control for any possible differences due to the area studied. An in depth analysis of cases where these failure types occurred could also be carried out in order to clarify both road user attributes and more complex roadside data in order to magnify some of the selected factors.
Acknowledgment
This paper uses accident data from the United Kingdom On The Spot Accident Investigation (OTS), which is funded by the Department for Transport (DfT) and Highways Agency (HA). The views expressed in this paper belong to the authors and are not necessarily those of the DfT or HA.

REFERENCES
Brown, I.D. 2005 ‘Review of the ‘Looked but Failed to See’ Accident Causation Factor’
Mosedale, J. Purdy, A. And Clarkson E. 2004 ‘Contributory factors to road accidents’,
SETTING APPROPRIATE POSTED SPEED LIMITS
IN THE EMIRATE OF ABU DHABI

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ABSTRACT
Establishing speed limits that achieve public support is a prerequisite to developing any effective speed management program. Speed limits are selected to balance travel efficiency versus safety. A total of 60 sites were selected throughout the Emirate of Abu Dhabi where operating speed data were collected for 48 hours. The objective of the study is to provide rational posted speed limits in the Emirate, based on engineering studies and by using a computer program developed by the Federal Highway Administration (FHWA) called USLIMITS2.

USLIMITS2 is a web-based expert advisor system designed to assist practitioners in determining appropriate speed limits in speed zones. USLIMITS2 calculates the appropriate speed limit for a section of road through the consideration of the following information input including but not limited to: the operating speeds (85th percentile speed and median speed), the number of interchanges, the number of driveways, crash statistics, and presence/absence of adverse alignment, current statutory limit, average daily traffic, and roadside hazards. The findings from the 60 sites are summarized in a table where most of the posted speed limits were found to be appropriate, and new posted speed limits were recommended for 7 locations.

1  INTRODUCTION
Collisions are caused by the interaction of three main factors: road user factors, environmental factors and vehicle factors, either in isolation or more commonly in combination. Speeding – the driver behavior of exceeding the posted speed limit or driving too fast for conditions – has consistently been a contributing factor in approximately one third of all fatal crashes worldwide. Even if speeding is not a contributing factor in a crash, travel speed affects the severity of outcome.

Unlike many unsafe driver behaviors, faster speeds have positive benefits such as reduced travel times, greater mobility, and increased economic productivity. It is this subjective tradeoff of positive and negative impacts that makes an assessment of the speed management measures difficult. Thus speed management is not about reducing speeds but applying engineering, enforcement and education to achieve safe and appropriate speeds for conditions.

Speeding is a complex problem, involving the interaction of many factors including public attitudes, road user behavior, vehicle performance, roadway design and characteristics, posted speed limits, and enforcement strategies. To be successful, engineering, enforcement,
and education must be integrated and coordinated. No single technique can effectively accomplish the goal of reducing speeding related fatalities and injuries.

Establishing appropriate posted speed limits that achieve public support is a prerequisite to developing any effective speed management program. Speed limits are selected to balance travel efficiency versus safety. The following factors are usually considered when identifying the appropriate speed limits:

- Operating speeds (85\textsuperscript{th} percentile speed and median speed);
- Extent of pedestrian/bike activities;
- Number of interchanges within this section;
- Number of driveways and traffic signals in the section;
- Crash statistics;
- Presence/absence of adverse alignment;
- Current statutory limit;
- Area type;
- Section length;
- Terrain;
- Annual Average Daily Traffic;
- Roadside hazards; and
- Presence/usage of on-street parking.

The United States’ Manual of Uniform Traffic Control Devices (MUTCD 2003 Edition), adopted by most countries, notes that “when a speed limit is to be posted, it should be within 10 km/h or 5 mph of the 85\textsuperscript{th} percentile speed of free-flowing traffic”. Therefore, the major factors that should be considered in setting appropriate speed limit is the 85\textsuperscript{th} percentile speed. However, the above factors should also be considered when developing the appropriate speed limits. For example, pedestrian activities are crucial throughout urban areas.

In this paper, the Authors discuss the major issues associated with speeding, and highlight the procedure that was followed to evaluate and set appropriate posted speed limits on Abu Dhabi’s highways’ network.

2 \textbf{THE ROLE OF SPEED IN COLLISION RATES AND SEVERITIES}

Speeding is a key risk factor in road traffic injuries and has been identified as being critical in determining both the risk of a collision and the severity of injuries when they do occur. Higher levels of collision risks are associated with speeding because of greater stopping distances and the increased likelihood of losing control of a vehicle when velocities are higher. The higher the speeds in a collision, the greater the amount of kinetic energy that must be exchanged or absorbed upon impact. The amount of energy interchange that occurs during a collision strongly determines the severity of the resulting injury. There are three theoretical approaches that link speed with collision risk (TRB, 1998); 1) information processing; 2) traffic conflict; and 3) risk-homeostasis.

The information processing theory is based on the concept that the driver acts as a data processing unit with a limited capability. The faster drivers travel, the quicker they are required to process information. Therefore, at higher speeds there is less time for drivers to process information and react if an incident occurs that could result in a collision. For this reason, this theory supports a direct link between vehicle speeds and the likelihood of a collision.

The traffic conflict theory is based on the fact that differences between vehicle speeds can lead to conflict and collisions. The risk-homeostasis theory takes the approach that a driver
will adjust their speed according to the prevailing conditions and to maintain an acceptable level of risk. In this case, it is argued that driving at higher speeds is not in essence dangerous in itself, but it is rather that driving too fast for conditions increase the likelihood of involvement in a collision.

2.1 The Affect of Average Speed on Collision Rates and Severity
In the United States, approximately one third of all fatal crashes cite speeding as a major contributory factor (Milliken, 1998). In a meta-analysis of results from a number of countries, Finch, Kompfner, Lockwood, and Maycock (1994) found that a 1 km/h reduction in average speeds was associated with a 3 percent reduction in crash rates. In a detailed study in United Kingdom on rural roads, Taylor, Baruya, and Kennedy (2002) found the figure to range from 2-5 percent reduction, depending on the average speed.

Nilsson (2004) found the crash rate increased in proportion with the ratio of average speeds squared. That is to say, if the average speed increased by 10 percent, one could expect a 21 percent increase in the crash rate. This relationship was also verified empirically based on historical crash data (Elvik, Christensen, and Amundsen, 2004).

The likelihood of being involved in a serious or fatal collision increases significantly with even minor increases in the speed of impact (GRSP, 2008). The relationship between crashes and speed has been modelled by Nilsson (2004), as shown in Figure 1. The graph in Figure 1 shows the relationship between percentage change in speed and the percentage change in fatal, serious and injury crashes.

![Figure 1: Illustration of the ‘power model’ and the relationship between percentage change in speed and the percentage change in fatal, serious and injury crashes](image)

The model illustrates that an increase in mean speeds of 5 percent leads to an increase in injury crashes of 10 percent, and more than a 20 percent increase in fatal crashes. Similarly, if mean speeds were to decrease by 5 percent, then a reduction in all injury crashes of 10 percent and a reduction in fatal crashes of around 20 percent can be expected (OECD, 2008). There is an extensive body of evidence supporting this model (OECD, 2008). In particular, the meta-analysis completed by Elvik, Christensen, and Amundsen (2004) that brought...
together evidence from 98 studies where most of these studies compared well to the Nilsson’s model.

2.2 The Effect of Speed Differential on Crash Rates

The variation in speed of different road users on a given road section is known as the speed differential. Consider the case where three vehicles are travelling in the same direction on one carriageway of a three-lane freeway. If their speeds are exactly the same and their course of travel is the same, then the relative velocity of the vehicles to each other is zero. In this situation, there is no potential for conflict, all else being equal. However, if vehicles are travelling at different speeds, particularly the case where different types of traffic are using the same road, and in different directions, the speed differential can be considerable.

Some studies have shown that speed differential is an important factor influencing collision rates and outcomes (e.g., Solomon, 1964). This is driven by the higher potential for conflicts with higher differential velocities and therefore the need to dissipate or transfer large amounts of kinetic energy in a collision.

Three studies were undertaken in the United States more than 40 years ago to quantify the relationship between accident risk and speed differential (e.g. Solomon, 1964). The studies were undertaken on rural roads and they reported a U-shaped relationship as shown below in Figure 2. This shows that where differentials speed is highest (at the extremes of the x-axis), crash rates are highest.

![Figure 2: Result of Solomon (1964) crash involvement rate by variation from average speed, day and night](image)

Table 1 provides a summary of findings from studies in several countries where speed limits have either been increased or decreased.
Table 1: Summary of results from speed limit changes

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Change</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed Limit Decreases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nilsson (1990)</td>
<td>Sweden</td>
<td>110 km/h to 90 km/h</td>
<td>Speeds declined by 14 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fatal crashes declined by 21%</td>
</tr>
<tr>
<td>Engel (1990)</td>
<td>Denmark</td>
<td>60 km/h to 50 km/h</td>
<td>Fatal crashes declined by 24%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury crashes declined by 9%</td>
</tr>
<tr>
<td>Peltola (1991)</td>
<td>UK</td>
<td>60 mph to 50 mph (100 km/h to 80 km/h)</td>
<td>Speeds declined by 4 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crashes declined by 14%</td>
</tr>
<tr>
<td>(Finch et al., 1994)</td>
<td>Switzerland</td>
<td>130 km/h to 120 km/h</td>
<td>Speeds declined by 5 km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fatal crashes declined by 12%</td>
</tr>
<tr>
<td>Scharping (1994)</td>
<td>Germany</td>
<td>60 km/h to 50 km/h</td>
<td>Crashes declined by 20%</td>
</tr>
<tr>
<td>Newstead &amp; Mullan</td>
<td>Australia</td>
<td>5-20 km/h decreases</td>
<td>No significant change</td>
</tr>
<tr>
<td>(1996)</td>
<td></td>
<td></td>
<td>(However 4% increase relative to sites not changed)</td>
</tr>
<tr>
<td>Parker (1997)</td>
<td>USA</td>
<td>5-20 mph decreases (8-32 km/h decreases)</td>
<td>No significant changes</td>
</tr>
<tr>
<td></td>
<td>22 states</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Speed Limit Increases</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHTSA (1989)</td>
<td>USA</td>
<td>55 mph to 65 mph (89 km/h to 105 km/h)</td>
<td>Fatal crashes increased by 21%</td>
</tr>
<tr>
<td>Garber &amp; Graham</td>
<td>USA</td>
<td>55 mph to 65 mph (89 km/h to 105 km/h)</td>
<td>Fatalities increased by 15%</td>
</tr>
<tr>
<td>(1990)</td>
<td>(40 States)</td>
<td></td>
<td>Decrease or no effect in 12 States</td>
</tr>
<tr>
<td>Streff &amp; Schultz (1991)</td>
<td>USA</td>
<td>55 mph to 65 mph (89 km/h to 105 km/h)</td>
<td>Fatal and injury crashes increased significantly on rural freeways</td>
</tr>
<tr>
<td>(Michigan)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pant, Adhami, &amp;</td>
<td>USA</td>
<td>55 mph to 65 mph (89 km/h to 105 km/h)</td>
<td>Injury and property damage crashes increased but not fatal crashes</td>
</tr>
<tr>
<td>Niehaus (1992)</td>
<td>(Ohio)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sliogeris (1992)</td>
<td>Australia</td>
<td>100 km/h to 110 km/h</td>
<td>Injury crashes increased by 25%</td>
</tr>
<tr>
<td>Lave &amp; Elias (1994)</td>
<td>USA</td>
<td>55 mph to 65 mph (89 km/h to 105 km/h)</td>
<td>State-wide fatality rates decreased 3-5%</td>
</tr>
<tr>
<td></td>
<td>(40 states)</td>
<td></td>
<td>(Significant in 14 of 40 States)</td>
</tr>
</tbody>
</table>

Although there is some variation, the studies in Table 2 show that where speed limits have been reduced, there are generally benefits in terms of the number and severity of collisions.
Conversely, where speed limits have been raised, generally an increase in the number and severity of collisions can be seen. One likely source of the variation in the results in Table 2 is likely to be that not all relevant factors can be controlled for in such empirical studies. Some of the information in Table 2 appears to be contradictory, for example Lave and Elias (1994) found a decrease in crashes in the United State when speed limits were raised; however, other studies based on the same change in speed limits found that crash rates increased.

3 SPEED LIMIT SETTING METHODOLOGIES
To investigate a speed limit setting approach that would be suitable to use in the Emirate of Abu Dhabi, four speed limit methodologies were considered:

- X-LIMITS;
- USLIMITS2;
- Functional Basis; and
- Safe System.

The four methodologies are described and were considered in relation to the respective countries that utilise the various approaches. A summary is included below.

3.1 X-LIMITS
X-LIMITS is a computer based tool kit for setting speed limits based on expert analysis and input as well as extensive trials. The tool, used by Australia and New Zealand, takes into account road function, road geometry, type of median, surrounding development, type of road users, crash history, existing operating speeds and surrounding speed limits (GRSP, 2008).

The approach to setting speed limits in X-LIMITS is based on a set of national or regional speed limits supplemented by the ability to set local speed limits in extra ordinary situations. The X-LIMITS system is based on a survey of the road conditions and environment.

For example in New Zealand, the two national speed limits are:
- 50km/h in urban areas; and
- 100km/h in rural areas.

In addition, 60, 70 and 80km/h speed limits can also be used.

The rules for setting speed limits in New Zealand are detailed in “Speed Limits New Zealand” (SLNZ) (Land Transport New Zealand, 2003). During the survey, a number of features are taken into account as detailed below:

- The character of the surrounding land environment (e.g. rural, fringe of city, fully developed);
- The function of the road (i.e. arterial, collector or local);
- Detailed roadside development data (e.g. Number of houses, shops, schools, etc.);
- The frequency and nature of side roads;
- Carriageway characteristics (e.g. median divided, lane width and number of lanes, road geometry, street lighting, footpaths, cycle lanes, parking, setback of fence lines from carriageway);
- Vehicle, cycle and pedestrian activity;
- Crash data; and
- Speed survey data.
The above factors are combined in a survey to produce a “road rating” for a section of road and this rating determines the speed limit that should be in force.

3.2 USLIMITS2

The US uses a similar system to that of New Zealand and Australia that is called USLIMITS2. Speed limits were set on a Federal basis until 1995 where after the power to set speed limits was devolved to the State level.

The USLIMITS2 approach is a tailored extension to X-LIMITS that is appropriate to the United States. It was refined by a panel of experts as well as an extensive survey of users of the software tool (Srinivasan, Parker, Harkey, Tharpe, and Sumner, 2006). A key difference between the United States and other X-LIMITS countries is that roads are categorised by functionality but speed limits can be within a set range of speeds rather than being set at specific speeds. The categories and speed ranges are listed below:

- Limited Access Freeway – 55mph (88km/h) to 75mph (120km/h);
- Road Section in Undeveloped Area – 40mph (64km/h) to 65mph (104km/h); and
- Road Section in Developed Area – 25mph (40km/h) to 50mph (80km/h).

The developed area speed limits are further categorised as follows:
- Residential Subdivision/Neighbourhood Street;
- Residential Collector Street;
- Commercial Street; and
- Street Serving Large Complexes.

Speed limits above 75mph (120km/h) are not recommended and the only exceptions to this maximum recommended speed limit are on sections of the I-10 and I-20 freeways in Texas, where the speed limit is 80mph (128km/h). The full list of variables considered for setting freeway speed limits is specified below:

- Operating Speed: 85th percentile speed and 50th percentile speed;
- Presence/absence of adverse alignment;
- Is this section transitioning to a non-limited access highway?;
- Section Length;
- Current statutory limit for this type of road;
- The terrain;
- Annual Average Daily Traffic;
- Number of Interchanges within this section; and
- Crash Statistics.

3.3 United Kingdom’s Functional Basis

Guidance on the setting of speed limits is provided by the Department for Transport circular 01/2006, Setting Local Speed Limits (DfT, 2006). This guidance states that the overall speed limit framework, including the setting of national limits for different road types, and which exceptions to the general limits can be applied, is the responsibility of the government. The three national speed limits are:

- The 30 mph (50 km/h) speed limit on street lit roads;
- The national speed limit of 60 mph (100 km/h) on single carriageway roads; and
- The national speed limit of 70 mph (120 km/h) on dual carriageways and motorways.
These national limits are not, however, appropriate to all roads. The speed limit regime enables Highway authorities to set “local speed limits” in situations where local needs and considerations deem it desirable for drivers to adopt a speed which is different from the respective national speed limit.’ (DfT, 2006).

The ‘local speed limits’ are determined by the characteristics of the road and what it looks like to road users. The existing speed of traffic and crash record should also be taken into account. Prior to the publication of Circular 01/2006 (DfT, 2006), the speed limit should have been based on the 85th percentile speed; however it should now be based on the mean speed. A summary of the general characteristics for roads with speed limits below 60 mph (100 km/h) are shown in the table below.

Table 2: United Kingdom benchmark criteria for ‘setting local speed limits’

<table>
<thead>
<tr>
<th>Speed Limit mph (km/h)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (32)</td>
<td>In town centres, residential areas and in the vicinity of schools where there is a high presence of vulnerable road users.</td>
</tr>
<tr>
<td>30 (48)</td>
<td>The standard limit in built-up areas with development on both sides of the road.</td>
</tr>
<tr>
<td>40 (64)</td>
<td>Higher quality suburban roads or those on the outskirts of urban areas where there is little development. Should be few vulnerable road users. Should have good width and layout, parking and waiting restrictions in operation, and buildings set back from the road. Should wherever possible cater for the needs of non-motorised users through segregation of road space, and have adequate footways and crossing places.</td>
</tr>
<tr>
<td>50 (80)</td>
<td>Usually most suited to special roads, dual carriageway ring or radial routes or bypasses which have become partially built up. Should be little or no roadside development.</td>
</tr>
</tbody>
</table>

It should be noted that in the United Kingdom, 30 km/h speed limits are only allowed if observed speeds are already 30 km/h or lower. This is usually achieved by the introduction of physical traffic calming measures or through road layouts that restrain speed. In other words these roads are self-enforcing. Different speed limits apply for different classes of vehicles, for example, on a 70 mph (120 km/h) dual carriageway Heavy Goods Vehicles are restricted to 50 mph (80 km/h) and Passenger Carrying Vehicles (vehicles with more than 8 seats excluding the driver) are restricted to 60 mph (100 km/h).

3.4 Swedish Safe-System

In Sweden, the concept of a safe speed, as originally discussed by Tingvall and Haworth (1999), also referred to as “Vision Zero” (Whitelegg and Haq, 2006), has been adopted as a basis for considering appropriate speed limits. The basis of safe speed is that the driver/vehicle/road system should operate such that, in the event of a crash, forces are not exerted on vehicle occupants or other road users which are likely to lead to a fatality. The
focus is on reducing the severity of injury for those crashes that do occur rather than purely reducing injuries through crash prevention.

This means that, where pedestrians are present, vehicle speeds should be no higher than 30 km/h. Where vehicle to vehicle crashes occur they should be at speeds below the impact speeds at which cars can be shown to safeguard occupant life. Ratings are being developed through the European Road Assessment Programme (EuroRAP) showing how well the road is designed to ensure forces involved in impact with road infrastructure also keep within the same thresholds, and these are being used in Sweden to indicate appropriate speed limits for roads with different ratings. The following table provides a summary of the speed limits that would be in place based on this approach.

Table 3 – Speed limits based on safe speed concept

<table>
<thead>
<tr>
<th>Road type/traffic situation</th>
<th>Safe Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads with potential conflicts between cars and unprotected road users</td>
<td>30</td>
</tr>
<tr>
<td>Intersections with potential side impacts between cars</td>
<td>50</td>
</tr>
<tr>
<td>Roads with potential head-on conflicts between cars</td>
<td>70</td>
</tr>
<tr>
<td>Roads where head-on and side impacts with other road users are impossible</td>
<td>≥100</td>
</tr>
</tbody>
</table>

The basic speed limits in Sweden are:
- 110 – 120 km/h on Highways;
- 90 km/h on other roads;
- 50 km/h in urban areas; and
- 30 km/h around schools and daycare centres.

4 FINDINGS AND RECOMMENDATIONS FOR ABU DHABI

Of the international practices reviewed and detailed above, the roadway network in Abu Dhabi has the greatest level of similarity with the United States. Therefore, for the purposes of this project, the guidance in the National Cooperative Highway Research Program Research Results Digest 318 (NCHRP, 2007) and USLIMITS2 were adopted to determine the speed limits on the network.

An important element of a speed strategy is that drivers should have confidence in the reliability and consistency of speed limits. Speed limit information should be easy for the driver to identify and relevant for the respective road characteristic. For this reason, most international practices are to have a series of speed limits that are applied to roads dependent on their nature and performance in the road network. It is proposed that this approach should be replicated on Abu Dhabi’s roadway network and there will be three based speed limits as follows:
- 120 km/h limit on the high quality roads (e.g., divided multilane highways);
- 100 km/h limit on lower quality rural roads (e.g., undivided two-lane rural highways);
- 80 km/h limit on rural truck routes and in areas with limited conflict between pedestrians and vehicles.

Speed limits for urban roads are not being considered in this report and the focus was on roads with 80 km/h and higher.

To evaluate the current conditions on the roadway network, speed spot surveys were undertaken at 60 points. The surveys were undertaken for a period of 48 hours at each site.
using either Metrocount or Numetric data recorders, generally depending on the number of traffic lanes at the survey point. For roads with 3 lanes or less Metrocounters were used. For roads with 4 lanes or more Numetric counters were used. Metrocounters devices use rubber tubes across the road to measure vehicle speeds, Numetric counters are based on measuring magnetic resonance. The data collected was then analyzed to establish the 85th and 50th percentile operating speeds at each site. Only free flow speeds were considered (i.e., any vehicles with a headway of less than 4 seconds were removed from the data).

The results were then analyzed to establish current driving conditions and to provide recommendations on appropriate speed limits at each of the survey points. The survey sites were chosen to provide a cross section of the network and were not chosen to examine any particular concern or safety issue. As such no selection criteria was created and the survey locations were selected to cover typical links in the network. To maximize the coverage of the network several sites were only recorded in one direction.

The survey results were analyzed to calculate a posted speed limit in accordance with the recommendations in USLIMITS2. A summary of the results is shown in Table 4.

Table E1 – Summary of speed survey results (all speed figures are in km/h)

<table>
<thead>
<tr>
<th>Survey Points</th>
<th>Road Limit</th>
<th>Existing Limit</th>
<th>Proposed Limit</th>
<th>USLIMITS</th>
<th>85th%ile Speed†</th>
<th>50th%ile Speed†</th>
<th>Standard Deviation</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E15</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>73</td>
<td>21</td>
<td>3,900</td>
</tr>
<tr>
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<td>100</td>
<td>100</td>
<td>(100)</td>
<td>156</td>
<td>124</td>
<td>27.8</td>
<td>2,750</td>
</tr>
<tr>
<td>3</td>
<td>E65</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>125</td>
<td>97</td>
<td>25.4</td>
<td>1,100</td>
</tr>
<tr>
<td>4</td>
<td>E11</td>
<td>100, 80</td>
<td>100</td>
<td>(100)</td>
<td>160</td>
<td>126</td>
<td>35</td>
<td>8,400</td>
</tr>
<tr>
<td>5</td>
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<td>100, 80</td>
<td>100</td>
<td>(100)</td>
<td>151</td>
<td>117</td>
<td>29.9</td>
<td>8,400</td>
</tr>
<tr>
<td>6</td>
<td>E11</td>
<td>100, 80</td>
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<td>(100)</td>
<td>142</td>
<td>100</td>
<td>30.8</td>
<td>5,000</td>
</tr>
<tr>
<td>7</td>
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<td>(100)</td>
<td>141</td>
<td>103</td>
<td>29.5</td>
<td>5,000</td>
</tr>
<tr>
<td>8</td>
<td>E95</td>
<td>100</td>
<td>120</td>
<td>(120)</td>
<td>142</td>
<td>113</td>
<td>27.6</td>
<td>3,300</td>
</tr>
<tr>
<td>9</td>
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<td>120</td>
<td>(120)</td>
<td>139</td>
<td>107</td>
<td>27.4</td>
<td>3,300</td>
</tr>
<tr>
<td>10</td>
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<td>100</td>
<td>120</td>
<td>(120)</td>
<td>139</td>
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<td>100</td>
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<td>23.4</td>
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<td>8,000</td>
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<td>154</td>
<td>129</td>
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<td>154</td>
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</tr>
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<td>Survey Points</td>
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<td>50th%ile Speed†</td>
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<tr>
<td>47</td>
<td>E33</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>132</td>
<td>109</td>
<td>21.4</td>
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</tr>
<tr>
<td>48</td>
<td>E30</td>
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<td>100</td>
<td>130</td>
<td>106</td>
<td>21.7</td>
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</tr>
<tr>
<td>49</td>
<td>E30</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>124</td>
<td>103</td>
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<td>22,000</td>
</tr>
<tr>
<td>50</td>
<td>E2</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>110</td>
<td>89</td>
<td>19.3</td>
<td>21,500</td>
</tr>
<tr>
<td>51</td>
<td>E2</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>107</td>
<td>88</td>
<td>17.6</td>
<td>21,500</td>
</tr>
<tr>
<td>52</td>
<td>S4</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>97</td>
<td>78</td>
<td>18.9</td>
<td>37,000</td>
</tr>
<tr>
<td>53</td>
<td>E10</td>
<td>80</td>
<td>80</td>
<td>-</td>
<td>146</td>
<td>114</td>
<td>26.9</td>
<td>44000</td>
</tr>
<tr>
<td>54</td>
<td>E1</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>88</td>
<td>73</td>
<td>14.3</td>
<td>28,000</td>
</tr>
<tr>
<td>55</td>
<td>E1</td>
<td>60</td>
<td>60</td>
<td>-</td>
<td>88</td>
<td>73</td>
<td>14.2</td>
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<td>56</td>
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<td>80</td>
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<td>21,500</td>
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<td>105</td>
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<td>17.22</td>
<td>44000</td>
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<td>59</td>
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<td>120</td>
<td>120</td>
<td>120</td>
<td>151</td>
<td>122</td>
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<td>10,000</td>
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<tr>
<td>60</td>
<td>E11</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>144</td>
<td>111</td>
<td>27, 25.9</td>
<td>10,000</td>
</tr>
<tr>
<td>61</td>
<td>E30</td>
<td>80</td>
<td>80</td>
<td>100</td>
<td>117</td>
<td>83</td>
<td>25.6</td>
<td>4250</td>
</tr>
</tbody>
</table>

† The 85th percentile is the value (of free-flow speed) below which 85% of the traffic is travelling, the 50th percentile is the speed below which 50% of vehicles are travelling.

† (100) 50th percentile speed adjusted to remain within parameters of USLIMITS2.
REFERENCES
Garber & Graham (1990). The Effects of the New 65 Mile Per Hour Speed Limit on Rural Highway Fatalities: State by State Analysis,” Accident Analysis & Prevention, V22 (2).
Scharping (1994). Experience Report. 30 Km/H Speed Limited Zones in Hamburg. Speed Reduction Measures on Major Inner City Roads, Transportation Research Institute, Technion-Israel Institute, Haifa, Israel.
USLIMITS2 Retrieved from http://www2.uslimits.org/
KNOWING YOUR SPEED CAN SAVE YOUR LIFE

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ABSTRACT
Encouraging motorists to drive/ride below the speed limit is particularly important because
motorist error constitutes the greatest likelihood of majority of the accidents. Driver
Feedback Sign (DFS) that tell motorists their real time speeds and remind them to obey the
speed limit, have been recently installed at a few locations in Singapore. This paper presents
the evaluation findings and recommendations of the signs. The quantitative evaluation
indicates that the DFS is effective in reducing the speeds of vehicles and accident numbers.

1 INTRODUCTION
Research (Evans, 1991) has shown that the predominant role of “human” component in
almost all the road traffic accidents, is either independently or combined with other factors.
Our road accident statistics found that about 32% of the fatal accidents were speed-
related; as did 21% of the injury accidents (Source: Raw data is from Traffic Police). It is
also found that the likelihood of speed-related accidents being fatal is greater compared to
other types of accidents. As such, more still need to be done to curb speeding problems.
Speed management is defined as an active approach that requires or persuades drivers to
adopt speeds that offer mobility without compromising safety (GRSP, 2008). Speed
management has always been in the mind and remains as a major challenge of all road safety
practitioners in the world. The higher the travelling speed is, the longer stopping distance is
required and hence the increased risk of a crash. Excessive speed is associated with higher
kinetic energy which results in greater impact and injury severity in the event of an accident.
Studies (Kloeden et al. 1997; ERSO, 2007) proved direct evidence that the risk of
involvement in a casualty crash has an exponential relationship with the increase in travelling
speed.

2 VARIOUS FORMS OF TRAFFIC CALMING
There are various forms of traffic calming, ranging from physical engineering measures to
enforcement. Typically, physical measures mean the traditional vertical or horizontal vehicle
deflections which forcefully reduce the vehicle speeds after a physical huddle such as humps
or chicanes. Though effective, these measures are known to be associated with concerns
(Janet, 2005; Shauna et.al., 2007):
  a) Are generally unpopular with residents
  b) Can be expensive to build
  c) Encourage a style of driving involving a high degree of acceleration and
deceleration (air pollution)
  d) Can generate noise and vibration
  e) May cause discomfort to vehicle occupants
Enforcement forms the other extreme end of measure that is warranted typically after all engineering measures have been exhausted. Aberrant drivers are being ‘punished’ monetarily or through driving point penalties.

In the recent years, there has been a shift in the traffic calming paradigm to curb this driver behaviour that is, using psychological traffic calming. The concept of “building a road that seems dangerous and they would be safer” or “less-is-more” approach is spreading rapidly around the globe, showing up in Austria, Sweden, the UK and the US.

Psychological methods can include simple scheme like painting the lane with chevron markings to create a visually narrower lane, the naked street in Netherlands (Archdeacon, 2009) which is deliberately removed of all traffic signs and signals, leaving the motorists to share space with the pedestrians without any guidance and improve the motorists’ view characteristics via vegetation (PIARC, 2008).

One common principle of psychological methods is its function as an alternative traffic calming measure but still has its intent to retain a significant speed reducing capability. Displaying motorists’ speeds via an electronic sign board – Driver Feedback Sign (DFS) is another psychological (soft) engineering approach. It reminds motorists of their travelling speeds using a second ‘speedometer’ (see Figure 1) which is displayed in the motorists’ path of sight. Through the display of the motorists’ real time speeds, they are now more conscientious of their speeds and encouraged more to obey the posted speed limit.

The Department of Transport, UK, (Sustrans, 2004) found that average speeds can be reduced by 2-11km/h using such dynamic speed signs and also suggested that these signs are more effective on a mobile basis, since traffic may become immune when they are installed on a permanent basis. Other research results document that there is a 42% increase in the frequency of braking drivers (KLS Engineering, 2006) in school zones and the percentage of vehicles complying with the posted speed has increased by 30% (Eric, 2002), after installation of such devices.

Hence, DFS has been installed at 2 sites where its effectiveness in curbing speeding problem has been monitored.

![Figure 1: Driver Feedback Sign](image)

1190
3 METHODOLOGY
This section outlines the experimental design, hypotheses and measures of effectiveness for evaluating the DFS.

3.1 Site description
The selection of sites for installing DFS is based on the historical three years accident records. If the location meets the criteria of a black spot and majority of the accidents are speed related, it is qualified as a potential candidate for DFS installation. Currently, two sites are selected along expressway exits where the speed environment varies. A straight section of about 150m is required to provide a good sight distance of the sign to motorists, in order to deliver a clear meaning of the sign. Both sites are having similar traffic compositions and with the DFS located before a bend.

Site A
It is a 2-lane slip road that links from an expressway to residential area and it carries a daily traffic of 17,900 vehicles. The stretch of road operates at a speed limit of 50km/h and a slight upslope on the straight section followed by a right bend (see Figure 2). Existing traffic calming measures include “Slow” markings and “Bend Ahead” signs before the bend (see Figure 3).

Figure 2: Site A – Exit from Expressway (PIE)

Figure 3: Pre-DFS traffic calming measures
Site B
It is a 2-lane slip road that links from expressway to residential area and it carries a daily traffic of 25,900 vehicles. This stretch of road operates at a speed limit of 50km/h and it is a slight s-curvature layout (see Figure 4). Existing traffic calming measures include “Double Bend Ahead” signs and “Slow” markings (see Figure 5).

Figure 4: Site B – Exit from Expressway (SLE)

Figure 5: Pre-DFS traffic calming measures

3.2 Data collection

Part I: Accident data
Monitoring accident figures before and after intervention steps in is the most direct measure of effectiveness. Typically, three years of record are required for statistical significance. Nevertheless, the preliminary results are discussed here.

Part II: Driver behaviour (speed data)
Speed detector loops are installed parallel to the sign to capture speeds of vehicles 24-hourly before and after YSS has been installed. Using speed detector loops can improve the
accuracy of the speed data collected as motorists are not aware that their speeds are being monitored. It is also less labour intensive as compared to deployment of officers using portable speed gun. The speed detector loops also have the function to classify speeds by vehicle types automatically using axle numbers. One full week of data is collected 1 month before the installation (that constitutes the ‘before’ data) and 3 months after the installation (that constitutes the ‘after’ data). A decrease in speed is a measure of performance indicator that suggests that the sign is effective in moderating speeds.

Part II: Driver behaviour (vehicle brake lights)
Video footages are collected from the back view of motorists to observe the phenomenon of motorists pressing brakes before and after installation of DFS. A higher percentage of motorists pressing brakes would indicate that they are now more aware of their speeds and are more prepared to slow down before the bend.

Part III: Perception survey
This part of the evaluation study serves to complement Parts I and II on driver behaviour. It gathers view and acceptability level of the primary users (motorists) on the new scheme. It is a measure of customer satisfaction level. Respondents either are interviewed in carparks near to the 2 sites or self-filled the questionnaires with prepaid stamps.

4 FINDINGS AND RECOMMENDATIONS

4.1 Part I: Accident data
The accident figures (before and after implementation of DFS) are tabulated in Table 1. After normalizing the figures so that the pre and post implementation figures represent the same duration of months, the percentage drops in accident numbers are 89% and 90%. These preliminary results show substantial reduction in the number of accidents more than 1 year after the DFS has been implemented.

Table 1: Pre and post implementation of accidents at DFS sites

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of injury accidents</th>
<th>Pre-implementation (2005-2007)</th>
<th>Post-implementation</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site A</td>
<td></td>
<td>20</td>
<td>1</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(19 months)</td>
<td>(17 months)</td>
<td></td>
</tr>
<tr>
<td>Site B</td>
<td></td>
<td>26</td>
<td>2</td>
<td>83</td>
</tr>
</tbody>
</table>

4.2 Part II: Driver behaviour
The average drops in 85th percentile speeds during day time at Sites A and B are 4.5 and 4.4km/h (7% and 6% decrease) respectively; whereas those during night time are 1.8 and 3.8km/h (3% and 6%) respectively. There are greater drops in 85th percentile speeds during daytime than night time (7pm to 7am) (see Table 2). The speed reductions are comparable with overseas studies (KLS, 2006; Lee et. al., 2006; TMS, 2006) where similar DFS have been used.

Average speed data on a typical weekday is observed. There is no particular trend in the different hours of the day that DFS is particularly effective or not.
Table 2: 85<sup>th</sup> percentile speeds (km/h) before and after DFS installation

<table>
<thead>
<tr>
<th>Site</th>
<th>Day</th>
<th>Night</th>
<th>Site</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample</td>
<td>85&lt;sup&gt;th&lt;/sup&gt; %tile speed</td>
<td>Difference</td>
<td>Sample</td>
<td>85&lt;sup&gt;th&lt;/sup&gt; %tile speed</td>
</tr>
<tr>
<td>A</td>
<td>67,304</td>
<td>64.0</td>
<td>70,356</td>
<td>59.6</td>
<td>-4.5</td>
</tr>
<tr>
<td>B</td>
<td>86,928</td>
<td>68.2</td>
<td>77,957</td>
<td>63.8</td>
<td>-4.4</td>
</tr>
</tbody>
</table>

After DFS has been installed, the percentage of motorists observing the posted speed limit (of 50kph) increases at Sites A and B (by 9% and 14% respectively). These results are consistent with the observation from video footages, where Locations A and B show increases (8-9%) in the proportion of motorists pressing brake lights (see Table 3).

Table 3: Proportion of motorists pressing brakes before and after DFS installation

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Sample size</th>
<th>Number of motorists pressing brakes</th>
<th>Proportion of motorists pressing brakes</th>
<th>P-test (S/NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>M/c</td>
<td>18</td>
<td>18</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Car</td>
<td>107</td>
<td>120</td>
<td>78</td>
<td>97</td>
</tr>
<tr>
<td>LGV</td>
<td>69</td>
<td>49</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>HGV</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Bus</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>200</td>
<td>200</td>
<td>107</td>
<td>126</td>
</tr>
</tbody>
</table>

Site A

| M/c          | 6           | 11                                  | 3      | 3     | 0.50   | 0.27  | Significant at 93% confidence interval |
| Car          | 90          | 113                                 | 17     | 32    | 0.19   | 0.28  |                                             |
| LGV          | 88          | 65                                  | 6      | 7     | 0.07   | 0.11  |                                             |
| HGV          | 4           | 2                                   | 0      | 0     | 0.00   | 0.00  |                                             |
| Bus          | 12          | 9                                   | 0      | 0     | 0.00   | 0.00  |                                             |
| Total        | 200         | 200                                 | 26     | 42    | 0.13   | 0.21  | Significant at 95% confidence interval |

Site B

Generally, motorcycles are observed to be travelling at higher speeds as compared to the other vehicles (see Figures 6 and 7). DFS is shown to have greater effect in moderating the speed of goods vehicles as compared to those of motorcycles which have the least effect, in terms of percentage change. The probable reason why motorcycles do not show as much speed reduction as compared to the rest of the vehicles could be due to the mobile characteristics of motorcycles. They tend to travel alongside other bigger vehicles which diminish the detection of their speeds by the DFS. As such, this may provide the impression to motorcyclists that they are travelling at a lower speed.
4.3 Part III: Perception survey

The perception survey focused on the extent to which the DFS has improved the level of satisfaction with the motorists. A total of 122 samples are collected. All respondents have at least passed by sites before.

88 out of 122 respondents (72%) felt that installing DFS is effective in moderating motorists’ speeds. Some of the reasons that stood out are DFS serves as a reminder to motorists of their speeds and DFS acts as a warning sign when it blinks.

75% of the respondents know the speed limit (50km/h) of the locations. However, 39% of them felt that the speed limit at the locations could be higher. This suggests the likelihood of motorists disobeying the speed limit as they feel it is safe to do so. This is supported by speed data where only 37% and 16% of the motorists are travelling below the speed limit at Sites A and B respectively.

87% of the respondents noticed DFS; Of which, 64% of them think that DFS is accurate in telling the speed of their vehicles and another 22% did not bother to countercheck the speeds.
Other comments from the survey include 18 out of the 122 respondents (15%) felt either
the sign is too small or not catchy enough.

5 PUBLIC COMMUNICATION PLANS
To complete the loop of introducing a new measure successfully, an important step is required
for public communication. That is, to seek community support of the scheme. It is always
important to inform as well as to ‘listen’ to the public, so as to seek their understanding and
needs.

An effective communication plan serves to benefit the community and help the road
safety practitioners to achieve goals in the following ways:
   a) Encourage informed participation – public feel their importance as part of the
      transport system and work cooperatively in dialogue session to benefit the whole
      community
   b) Build community pride and satisfaction – public seek to understand the authority
      intent of the scheme and support the scheme
   c) Improve service quality – road safety practitioners can feel pride in their work to
      satisfy the community at large and continue to strive for more useful schemes

Hence, for this DFS scheme, a comprehensive community plan has been developed. It
includes publishing the launch of the schemes via television, radio and print media. In
addition, posters and brochures in the form of cartoon animation have been produced to
convey the meaning of the DFS through an interesting way to the public (see Figure 8). These
posters and brochures have been distributed to HDB estates via their mail boxes as well
as through the community outreach events. Similar information on the scheme has also been
uploaded in the frequently used public domain website on road matters. In fact, the perception
survey forms also part of the communication plan, as it aims to get public views of the
scheme. All these efforts have been paid off by the well-received response from public of the
scheme.

6 CONCLUSION
From the accident data, Locations A and B are having substantial improvement (about 90%
decrease in accident numbers) over the past 1 year after DFS has been implemented. Driver
behaviour study has also shown decrease in speeds (6-7%) as well as improvement in the
compliance to speed limit (9-14%). The improvement over speeds may not be substantial.
This could be due to motorists still adjusting their behaviour in the first few months, but the
overall improvement has been demonstrated by the accident data. The perception survey
results also suggest that the majority are supporting the use of DFS to moderate motorists’
speeds. As all the evaluation results have demonstrated that DFS has successfully, in one way
or another, encouraged more motorists to countercheck and moderate their speeds, DFS is a
useful tool for traffic calming and it can save your life.

It is recommended to install DFS at more locations on a need-to basis as overuse of DFS
can also reduce any positive effects they may have.

REFERENCES
future of cities. Available from web
09.


Figure 8: Posters and brochures for public communication
Abstract
The scope of this paper is to assess drivers’ risk perception of the geometric characteristics by monitoring-examining drivers’ behaviour when driving on rural roads for a variety of car types having different engine power.

The setup of the research was to monitor driving behaviour of 12 different drivers, driving 4 different vehicle types on 3 typical section of rural road network.

The monitoring of driving behaviour was recorded using VBOX II and VideoVbox devices, which are Differential GPS based set of instruments, including a 3D accelerometer (Inertial Measuring Device).

In order to assess driver’s perception, the trial tests, were carried out trying to eliminate any kind of interference of other moving vehicles, humans or animals in order to avoid false data recording.

The present paper presents the results of a research effort, which is dedicated to the detailed drivers’ behaviour analysis. The first remarkable observations are:

- The engine power of the vehicle leads to higher speed values for experienced drivers. The inexperienced drivers do not drive very fast in any case. All the drivers show aggressive behaviour when driving a sport car.
- When driving vehicles with big engine power, the increasing rate of acceleration-deceleration is higher. This means that drivers’ risk perception is reverse proportional to the safety feeling of driving powered cars.
- For experienced drivers, the deceleration rate is much higher the acceleration rate. This can be explained by the fact that the experienced drivers are generally underestimating the risk, or overestimating their driving skills.

A lot of research has to be done on drivers’ behavioural analysis, in order to achieve better road alignment designs (beyond standard regulations and guidelines) and better signing, with emphasis to safety.

1 INTRODUCTION
Vehicle’s type and engine’s power are two dominating parameters regarding driver’s risk perception of the geometric characteristics.

The existing passenger car fleet in Greece includes a variety of types, models etc, so in order to get the most useful results it was mandatory to select the most typical passenger cars. 4 types of passenger cars were selected, equipped with different horse power engines: A city car 800cc (50hp), a typical passenger car 1600cc (115hp), a SUV car 1600cc (90hp) and a 2seater sports car 1800cc (150hp).

In order to assess driver’s behaviour, a new recording and evaluating methodology of vehicle’s movement dynamics, such as speeding profile, 3d-accelerating profile, trajectory, roll angle, yaw rate etc., is presented in this paper.
This methodology can contribute to a deeper research of a variety of issues affecting driver’s risk perception of the road characteristics, such as:

- 3D Road geometric design.
- Environment (Natural or Urban).
- Weather conditions
- Lighting conditions
- Roadside access
- Intersections’ at grade geometrics
- Pavement’s operational condition
- Traffic flow characteristics

The record-ability of these parameters can improve the interpretation of motorcyclists’ behaviour by giving a boost to the understanding of their risk perception.

It is obvious that this kind of research will help road designers to adopt safer road design standards, beyond regulations and guidelines.

2 BASIC PARAMETERS ANALYSIS

2.1 VEHICLE’S TYPE & ENGINE POWER.
A few papers are referring to the correlation between vehicle’s type & engine power type and the risk perception of the road geometric characteristics.

Although it should be easy to conclude that driving a bigger vehicle or a vehicle equipped with a more powerful engine, leads to a lower risk perception, it is not so, because there are several factors affecting actually the risk perception. (Kanellaidis, G, 1996)

The low engine power vehicles can result to a smoother and safer driving style, while the high engine power vehicles can result to a safer driving style because they can provide the necessary power to a skilful driver and help him to avoid a conflict. Of course the over-self-estimation of a driver’s driving skills combined with the evolution of vehicles’ possibilities is considered a critical risk factor.

A big and heavy passenger car can lead to a lower risk perception because the drivers feel they are “more protected” against a collision and this some times leads to a misjudgement of risky road geometric characteristics.

2.2 DRIVING EXPERIENCE.
A lot of research work has been conducted concerning the dominating role of driving experience in driver’s risk perception of road geometry characteristics.

The overestimated perception of driving skills combined with underestimation of driving demands consist a significant problem regarding risk perception (Williams, A. F., 2003). We should also deal with the question, whether high self overestimation truly improves driving ability and whether this ability influences driver’s self perception of what kind of driving skills a certain situation demands. (Grayson G.B., 2006, Deery, H.A., 1999, Williams, A.F., 2003 and Farrow, J.A. and Brissing, P. 1990).

An important issue is to define the driving record that describes “the experienced driver”. It should contain not only the time of driving licence acquisition but the travelled distance as well.

3. EXPERIMENTAL PROCEDURE

3.1. EQUIPMENT
VBOX II and VideoVbox devices by Racelogic Ltd that were used for recording the vehicles’ movement characteristics are all based on differential device GPS that offers great accuracy in relevant movements measurements. Measured velocities have an accuracy of ± 0.01 km/h and the same goes for estimated accelerations.

The Devices used set (fig. 1) includes a central unit where a GPS antenna, a braking sensor and a Inertial Measurement Unit, (3D Accelerometer).

VBOX II and VideoVBOX can collect almost the entire vehicle’s movement relevant data without the presence of a PC unit. Special software is used for data process that can reproduce the vehicle’s movement, showing all selected parameters (fig.2), while at the same time it provides graphic display of the vehicle’s trajectory, with reference to the roadway boundaries at the same time with the change of the vehicle’s movement parameters.(fig.3). The innovative element of Video Box is that it offers us the possibility of visual assessment of the driver’s behaviour all along the way.

Figure 1: VBOX II & VideoVbox. Vehicle’s movement characteristics recording devices.

Figure 2: VBOX II & VideoVbox. Real time visual inspection of vehicle’s movement characteristics combined with driver’s viewpoint.
Some of the movement characteristics and the relevant accuracy that are directly recorded are presented to the following Table 1:

Table 1: Measuring Specifications.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
<th>Accuracy using DGPS</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>0.1 km/h</td>
<td>0.1 km/h</td>
<td>0.01 km/h</td>
</tr>
<tr>
<td>Distance</td>
<td>0.05%</td>
<td>0.05%</td>
<td>1 cm</td>
</tr>
<tr>
<td>Position</td>
<td>3 m</td>
<td>1.8 m</td>
<td>1 cm</td>
</tr>
<tr>
<td>Elevation</td>
<td>6 m</td>
<td>3 m</td>
<td>1 cm</td>
</tr>
<tr>
<td>Acceleration</td>
<td>0.5%</td>
<td>0.5%</td>
<td>0.01 g</td>
</tr>
<tr>
<td>Heading</td>
<td>0.1 degrees</td>
<td>0.1 degrees</td>
<td>0.01 degrees</td>
</tr>
</tbody>
</table>

Other useful parameters that can be recorded are: Radius of turn, Heading, Trajectory layout.

3.2. PLANNING OF FIELD OPERATION TESTS

Road geometry

The problem of road safety is particularly much important in secondary national road network, due to narrower roads with higher curvatures and sharper slopes. Taking into consideration that the majority of these roads were designed several decades ago, it is obvious that they are not suited to the new generations of vehicles and their needs, so it was rational to set up the experimental procedure based on typical secondary national roads.

The geometry of the selected road, in order to monitor a driver’s behaviour, consists of segments with a variety of curvature radii and a variety of longitudinal slopes, (Figures 4 and 5). It is remarkable that in this road there is also a variety of road element combinations (high-low curvature, long-short straight lines etc), which is essential in order to establish an acceptable variation analysis of all the involved geometry parameters. The width of the road is no more than 7m, plus a shoulder of 0.5m on both sides and there is no lateral vegetation that affects visibility.
Figure 4: Layout of road section where monitoring of driver’s behaviour was conducted.

Figure 5: Longitudinal section of road section.

**Vehicles’ Fleet**
Four different types of passenger cars, by means of their horse power, were selected, a city car 800cc (50hp), a typical passenger car 1600cc (115hp), a SUV 1600cc (90hp) and a 2seater sports car 1800cc (150hp). The selection of cars was based on international classification and on the most common types travelling in Greece.

**Drivers’ Profile**
The differentiation of the drivers between experienced and non-experienced was based on:

i. the number of years that drivers possess a driver’s license,

ii. the average number of kilometers that drivers are running per year,

iii. previous drivers’ experience concerning cause or participation in a road accident,

iv. the drivers’ age.

In the experimentation, we monitored the behaviour of six drivers, two of whom were female and the other four were male, since according to national statistics, approximately one
third of drivers in Greece are female. Monitoring of driver’s behaviour has been conducted twice.

4. EXPERIMENTAL RESULTS.
The results are presented as diagrams:
• Speed vs. distance
• Acceleration vs. distance.
The diagrams from fig6 to fig13 are representative samples.
Fig. 8 Accelerating Profile - Non Experienced Drivers

- City Car 800cc
- S.U.V. 1600cc
- Passenger Car 1600cc
- Sport Car 1800cc

Fig. 9 Accelerating Profile - Experienced Drivers

- City Car 800cc
- S.U.V. 1600cc
- Passenger Car 1600cc
- Sport Car 1800cc
5. CONCLUSIONS.

The first conclusions that derive from the analysis of the results are:

- Experienced drivers have a higher speed, compared to non-experienced drivers, by 25.7% in the case of medium-power vehicles and by 28.3% in the case of high-power vehicles.
- Non-experienced drivers, when driving for the second time the same route, increase their speed by 5.5%, compared to the first time, whereas this increase of speed in the case of experienced drivers is 7.6%.
- Non-experienced drivers, when driving for the second time the same route, in the case of medium-power vehicles, have a speed increased by 11.0%, compared to the first time, whereas in the case of higher-power vehicles, increase of speed is 3.9%.
- Experienced drivers, when driving for the second time the same route, in the case of medium-power vehicles, have a speed increased by 3.8%, compared to the first time, whereas in the case of higher-power vehicles, increase of speed is 9.0%. The difference of percentages concerning the increase of average speed between the first and the second time among experienced and non-experienced drivers comes from the increased drivers experience and adaptation ability of experienced drivers compared to non-experienced ones.
- Female drivers, both experienced and non-experienced, are more careful, a fact which is strengthened in high-power vehicles.
- At the end of the curve, experienced drivers had a 12.0% higher speed compared to non-experienced drivers when driving a medium-power vehicle and a 23.2% higher speed when driving a high-power vehicle.
- As far as the average running speed of the curve is concerned, experienced drivers had a 18.9% higher speed compared to non-experienced drivers in the case of medium-power vehicles and a 25.2% higher speed in the case of high-power vehicles.
- Non-experienced drivers had almost the same speed at the beginning and at the end of the curve, regardless of the power of the vehicle.
- Experienced drivers when driving a high-power vehicle had a 7.3% higher speed at the beginning of the curve and a 10.9% higher speed at the end of the curve, compared to the running speed when they drive medium-power vehicles.
- Due to the small population survey, the above mentioned conclusions should be considered as indicative.

REFERENCES

Grayson G. B., (Transport Research Laboratory) and Groeger J. A., (University of Surrey),18-1-2006. «Risk, hazard perception and perceived control», Proceedings of the Novice Drivers Conference, Department for Transport.
Economic Appraisal and Optimization Process in Road Safety Projects

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Abstract

Setting a procedure to assess the efficiency in provision of the funds and operational expenses in road safety projects requires to establish a process involving the economic appraisal and optimization tasks. In the optimization process developed in the paper, five types of geometric features may be considered in the analysis including: (1) lane width and pavement condition, (2) horizontal curves, (3) vertical curves, (4) roadside condition, and (5) narrow bridges. The model enables the users to evaluate a variety of improvement alternatives for each predetermined geometric feature along the route under study, following which all possible mutually exclusive proposals are achieved for each site. Both calculating the executive costs and estimating the monetary benefits according to the reduction of road accidents for each proposal are the main components in estimating the net benefit attributable to each mutually exclusive proposal. Afterwards, an optimization process using linear integer programming is fed by the outputs of the cost-benefit analysis to find out the highest net benefit (as an efficiency criteria) among all provided proposals for all sites under study.

Keywords: Economic Appraisal, Optimization, Road Safety, Accident Modification Factors

1-Introduction

Generally, road safety is known as a condition involving all factors which reduce intensity and frequency of accidents, road injuries and its costs. This simple definition of road safety provides an explicit perception of two concepts consisting of road safety engineering and road safety management. Road safety engineering may be defined as a process, based on analysis of road and traffic related accident information, which applies engineering principles in order to identify road design or traffic management improvements that will cost-effectively reduce the cost of road accidents [1]. Road factor intensifies the human-errors in road accidents and it has been shown that a 30 to 40 percent decrease in accident can be saved through a safer road environment [2]. These evidences indicate the capability in removing geometric defects, enhancing road safety and its environment, and returning the spent investment in these areas by reducing the intensity and frequency of accidents.

Setting a procedure to assess the efficiency in provision of the funds and operational expenses in road safety projects requires establishing a process involving the economic appraisal and optimization tasks through this context:
- Optimized determination of road safety budgets in all governmental levels including national roads, state and local roads in the way that they can respond to all demands which relate to safety problems in all roads of a specific jurisdiction.
- Optimized determination of practices which are related to modifying road geometric or environmental defects as a specific defined budget as far as being assured that no other structure can supply the performance of selected practices.

In recent years, authorities pay too much attention to road safety projects evaluation. Actually, this increase in concentrating and attention has a direct effect on codification and setting appropriate implements for designers to obtain the most desired application/usage from pre determined budgets. This research can be a reasonable sample for reaching this goal.

2-Objectives
In this research evaluation process or in different words, resource allocation is considered for several and preselected locations. Therefore, the objective of this research is resource allocation, considering that this research concerns about resource allocation while in each location only one proposal must be chosen. Therewith, this subject is completely different with prioritization which concerns about priority and arrangement of locations according to necessity of funding. Hereon, we are distributing specific budget which is government funded and it’s under the control of responsible organization with these conditions:

- Choosing best possible improvement as the finest/best proposal among all choices according to accrued share of each locative situation that results the best net benefit and accordingly the sum of net benefits in all situations reaches its maximum amount, and
- Sum of all construction costs, relating to selected proposals in all locative situations, do not exceed the main budget.

3- Methodology
It will be an analytical research using data and documentary information with a quantitative procedure. This study presents a mathematical model attributed to two groups of optimization models and reliable statistic models observing proposed economical efficiency criteria. In this research only paved and non-freeway roads are under study. In fact, statistic models which used in this study for forecasting the accident rate related to road geometric and environmental features that collected based on previous studies in this field are the secondary information in model formation.

Improving road geometric features is explained as road safety projects in this research which is equivalent to black spot program in Iran. Thereby, definitions and frameworks in this research are different from usual rehabilitation projects in Iran. Also type of the roads which concerned in this study, of traffic and functional classification point of view, are mostly rural two-lane roads.

The model enables the users to evaluate a variety of improvement alternatives for each predetermined geometric feature along the rout under study, following which all possible mutually exclusive proposals are achieved for each site. Both calculating the executive costs and estimating the monetary benefits according to the reduction of road accidents for each proposal are the main components in estimating the net benefit attributable to each mutually exclusive proposal. Afterwards, an optimization process using linear integer programming is fed by the outputs of the cost-benefit analysis to find out the highest net benefit (as an efficiency criterion) among all provided proposals for all sites under study.
4- Geometric Features of the Model
In the analysis of the optimization model 5 groups of road geometric and environmental features can be considered:
1. Lane width and pavement surface condition,
2. Horizontal curves,
3. Vertical curves,
4. Roadside features, and
5. Narrow bridges.

The main reason for applying these 5 features is to access valid models for road crash prediction in Iran, for these geometrical road features. Technical and geometric features needed for the analysis of any of the aforesaid geometric road features are mentioned in table 1. For any of these geometric features an Accident Modification Factor (AMF) can be defined. This factor is defined as the ratio of crash rate in geometrical and environmental after safety improvement to crash rate before safety operation. Obviously, by accessing valid models for road crash prediction, we can define expedient relationships for each type of geometric feature.

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<tr>
<th>Road Feature</th>
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<td>Pavement Condition Index (PCI)</td>
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<td></td>
<td>Skid Number (SN)</td>
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<td>radius of the curve</td>
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<td>longitudinal slope factor</td>
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<td>lane width factor</td>
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<td>distance of the hazard from the road edge</td>
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<td>Narrow bridges</td>
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<td>slope coalition factor</td>
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</table>

5-Efficiency Index and Economic Appraisal Model
By using cost-benefit analysis method in this model as one of the best methods of economic appraisal, “net benefit” factor is presented as an efficiency index and analogy between models with each other. In this project, total benefit is defined as the present value of annual benefits resulting from crash reduction. Likewise, total costs include reconstruction and road rehabilitation executive costs, such as costs of lane widening and improving horizontal and vertical curves. Thereby, net benefit can be considered as a dependent variable of operant factors of road crash reduction and their construction costs. This net benefit is calculated separately for each section of the road, apart from other sections. In these components, benefit and costs can be defined as functions of other variables. The amount of total benefit in each section of the road is a function of annual crash reduction in that section. Also crash reduction
rate depends on geometric conditions before and after road improvement operation. Executive costs regarding each specific group of safety operations are calculated as a function of the volume of the same operations and as a whole, costs regarding all measures and improvement alternatives related to it. After presenting factors involved in the calculation of the benefit obtained from crash reduction rate, we can come to the relationship for calculating net benefit for each group of improvement operations which is a combination of a number of geometric features. This relationship is defined as equation 1 for each group of improvement operations:

\[ B_i = AN(1 - AMF_i)(r_F \cdot AC_F + r_I \cdot AC_I + r_{PDO} \cdot AC_{PDO})(P/A,r,N) - C_i \]  

(1)

Where:
- \( B_i \) = total benefit resulting from alternative group \( i \),
- \( AN \) = total number of accidents in existing situation,
- \( AMF_i \) = Accident Modification Factor for alternative group \( i \),
- \( r_F, r_I, \) and \( r_{PDO} \) = rate of fatal, injury, and property damage only accidents respectively (accident intensity distribution factors),
- \( AC_F, AC_I, \) and \( AC_{PDO} \) = the average cost of each fatal, injury, and property damage only accident respectively,
- \( r \) = discount rate,
- \( N \) = analysis period, and
- \( C_i \) = total executive cost for alternative group \( i \).

In this equation, the term within the second parentheses actually shows the weighted average of costs for each crash with the level of intensity. The phrase \((P/A,r,N)\) is also used to convert the total amount of annual benefit over \( N \) years of analysis period to its present value. The rate “\( r \)” is also the discount rate which is declared by governmental agencies.

6- Accident Modification Factors (AMFs)
AMF factor’s negative mark in relationship 1 indicates an inverse effect on crash reduction. In other words, the smaller AMF factor is than 1.0, the more crash reduction there will be. It is clear that when AMF is bigger than 1.0, crash rate is increased, which is incomprehensible in road safety literature. AMF factors are calculated based on crash models in Iran. Some AMF factors which are calculated by utilizing research carried out in Iran related to crash anticipation models are as follows:
- Accident Modification Factor for roadside features by using model of crash for roadside features [3]
- Accident Modification Factor for horizontal curves by using crash model for horizontal curves [4]
- Accident Modification Factor for road width and pavement condition by using the model of road pavement features and traffic volume on crash rate in rural two-lane roads [5]
- Accident Modification Factor for vertical curves [6]
- Accident Modification Factor for narrow bridges based on safety index in bridges [7]

7- Economic Appraisal and Optimization Process
In this optimization system, the purpose is to maximize the net benefit resulting from safety and geometric road improvement projects simultaneously in several different sites or routes, with a limited predetermined budget, noting that in each location only one group of safety
alternatives in the project can be selected as the best alternative. Later on in this project, we are going to discuss different stages involved in optimization process in road safety projects.

7-1- Step 1: Introducing the sites under study
In general, this stage of allocation process as the first step can be the result of earlier policies, studies, and activities involving prioritization of the road sections which need to be improved. Over the recent years, fundamental projects such as identifying and eliminating black spots have been done in this regard. Different indices, methods and models, presented in different research projects have also been utilized.

In surveying sites and roads, the minimum information listed below have to be collected for presenting each section of the road under study in resource allocation process and have to be involved in safety project’s basic reports.

- Site’s name
- Code of sites or sections under study
- A summary of the current condition of the road
- Topographical type of the site
- Road length
- Average daily traffic
- Annual crash rate
- Average speed of transportation vehicles
- Current width of traffic lane

7-2- Step 2: Recording the characteristics of the selected sites
This stage is another part of the process in which technical characteristics including environmental and geometric features and dimensions are recorded for those aspects of the project for which AMFs has been calculated by utilizing crash prediction models. These five aspects include lane width and pavement condition, horizontal curves, vertical curves, roadside features and narrow bridges. In further future studies, other aspects of road, such as at-grade intersections and traffic sings can be analyzed. At the beginning of the analysis process and in the primary stage of the safety project, a summary of safety problems which are highly probable to affect crash has to be provided. In this preliminary report, the technical and geometric features with all aspects considered in the optimization process are required to be recorded.

7-3- Step 3: Presenting suitable improvement proposals for each road
In this step, for each road section a set of improvement alternatives for every geometric feature, which requires safety enhancement and improvement, are presented as the primary alternatives of the model. For this purpose, all the geometric and technical features of those features mentioned in table 1, are recorded for post improvement situation. Along with giving every improvement element, executive costs of each element are also given by the user, which is for every road the total amount of improvement costs of every set of elements related to one road geometric feature is calculated by the model. Crash reduction factors for each improvement element and for each part of a road are the information that is calculated by the resource allocation model.

7-4- Step 4: Forming all the possible alternatives
In this step of resource allocation process, all the possible alternatives which consist of a combination of mutually exclusive proposals for each part of road, is formed by the model. In
other words, this step is done by the model and there is no need for the user to input the data. Formation of incompatible alternatives from a set of proposed alternatives works based on numeration of all possible combinations of alternatives. The number of incompatible alternatives for K various proposals is equal to \(2^k\) alternatives, and in case a binary variable of 1 or \(X_1=0\) is used for showing acceptance or refusal of a proposal, 32 possible alternative for 5 incompatible proposals, from \(P_1\) to \(P_5\) are listed in Table 2. In this table all the elements of \(A_0\) as the “do nothing” alternatives equal to zero, and in the opposite, all the suggested elements in \(A_{31}\) equal 1 which means accepting all the suggested alternatives. In this model, \(P_1\) to \(P_5\) alternatives consist of presented proposals for each part of road which in order introduces improvements related to road width and pavement surface condition, horizontal curves, vertical curves, roadside features and narrow bridges.

7-5- Step 5: Calculating safety benefit resulting from every combination of alternatives

After the formation of investment alternatives which consists of alternatives related to geometric improvement of road elements, the degree of total effect of each of these compound alternatives is evaluated by AMF compound factor in each part of road. In other words, for alternative \(j\) in road site \(i\), the AMF factor is resulted and this factor can calculate the reduced number of crashes in every improvement operation. At this end, total amount of benefits for every set of operations for alternative \(j\) and road site \(i\) is calculated as following:

\[
B_j = AN_i (1 - AMF_j)(r_f \cdot AC_f + r_j \cdot AC_j + r_{pdo} \cdot AC_{pdo})(P/A,r,N)
\]  \(15\)

It is noticeable that in equation 2, the \((P/A, r, N)\) factor is used to convert invariable amount of annual benefits resulting from crash reduction. Also in this relationship \(AN_i\) is the total amounts of current annual crashes in site \(i\).

7-6- Step 6: Calculating construction costs for each possible alternative

In general, construction costs related to each presented proposal by the user is a number that is given as input to the allocation model by the user. By forming investment alternatives, the total amount of executive costs of every combination of proposals is also calculated by the model. It is necessary for the executive costs to be considered based on the content of the proposals and the level of executive operation related to every geometric improvement in the plan.

7-7- Step 7: Calculating the net benefit for each alternative

Net benefit for each investment alternative is evaluated by calculating the difference between benefits and costs of each alternative - equation (1). This number is known as the efficiency criterion for each alternative, and by considering this criterion the most economical alternative is chosen among all the possible alternatives. Based on the definition, the “do nothing” alternative is referred to a situation in which none of the presented proposals have been accepted by the model. For this alternative, both ultimate net and executive costs of improvement operation equals to zero and thus net benefit also equals to zero.
### TABLE 5 Forming 32 alternatives by 5 proposals

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<tr>
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#### 7-8- Step 8: Running the optimization

After calculating the net benefit for each alternative in each part of road under study, in this step the best alternative among sites is selected in a way that the total amount of executive cost in all sites must be less than the given budget. The best alternative is defined as the safety operation which has the most net benefit. For this purpose the net benefit in all sites should be increased as long as it reaches the maximum value. In each site, only one of the alternatives can be selected among all alternatives and so the net benefits of these selected alternatives in all sites are added and reach the maximum amount. The other constraint, which is one of the most common constraints to define in most economical optimization plans, is called budget constraint, by which the maximum amount of costs for operating optimization in all sites is defined. Such objectives and constraints can be easily defined by using a binary linear programming method. The linear programming system is presented in equations 16 to 20.

Maximize: \(TB = \sum_{i=1}^{m} \sum_{j=1}^{n} NB_{ij} \cdot X_{ij}\)  \(\text{(16)}\)
Subject to:

\[ \sum_{j=1}^{n} X_{1j} = 1 \] (17)

\[ \sum_{j=1}^{n} X_{2j} = 1 \] (18)

\[ \vdots \]

\[ \sum_{j=1}^{n} X_{mj} = 1 \] (19)

\[ \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} \cdot X_{ij} \leq \text{Budget} \] (20)

In equation 16, the defined function is the objective function of linear programming system which makes the net benefit for all sites reach to the maximum value. Equations 17 to 19 are the constraints that show the selection of only one alternative among all compound alternatives. Equation 20 shows that the executive costs in all sites should not exceed the given budget. This system enables us to find the most efficient proposed elements for geometric improvement of all road sections for reaching the highest investment return.

8- Conclusion

Learning about road safety conditions (crash rate and technical features), knowing how to classify budgets and how to distribute them among competitive projects, diagnosing demands and deficiencies of road safety conditions, and finally choosing the proper and optimized ways for meeting these demands are the factors that make resource allocation process in road safety projects as one of the projects of asset management. For this purpose, it is necessary to utilize modern theoretical concepts in economic appraisal and optimization models and supporting software tools.

By operating optimization process based on the presented patterns in this paper, in case of dissatisfaction with the results regarding the definition of proposed elements given by the user, another set of geometrical improvement elements with different quantities can be used and analyzed in the allocation process. For instance, the type and the scale of improvement of horizontal curves in a site can be changed and optimization can be operated again and again in order to obtain the most desired improvement form. The process defined in this project may be utilized both for black spot programs and road safety audit activities.

References


SAFETY OF WIDER EDGE LINES IN THE USA

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ABSTRACT
One of the most important aspects of a safe and efficient roadway is the uniform application of pavement markings to delineate the roadway path and specific traffic travel lanes. Pavement markings can communicate information to road users like no other traffic control device because they provide continuous information to road users related to the roadway alignment, vehicle positioning, and other important driving-related tasks.

In the United States, almost $1 billion was spent on pavement markings on State-maintained roads in 2007. When local and private roads and parking areas are included, it is estimated that approximately $2 billion was spent on pavement markings in 2007 (Carlson 2009). Despite the national expenditures on pavement markings, a highway death occurs as a result of a lane departure every 21 minutes, according to a recent American Association of State Highway and Transportation Officials (AASHTO) report (AASHTO 2009). Prevention of roadway departure crashes is one of the Federal Highway Administration’s (FHWA) four focus areas for safety. In addition, AASHTO has developed its Strategic Highway Safety Plan that is designed to reduce these crashes (AASHTO 2008). The first objectives of the FHWA focus areas and AASHTO Safety Plan are to keep vehicles in their lanes and on the roadway. Installing and maintaining effective pavement markings is one immediate and obvious way to meet these objectives.

An on-going research study in the United States is focused on pavement markings and includes several topics: study the safety impacts, environmental impacts, and cost-effectiveness of different pavement marking systems and the effect of State bidding and procurement processes on the quality of pavement marking material employed in highway
projects. The research includes an evaluation of the impacts and effectiveness of increasing the width of pavement marking edge lines from the traditionally used width of 4 inches.

This paper presents preliminary findings from robust statistical analyses which provide strong quantitative support for the elusive link between pavement marking width and safety. The researchers used an Empirical Bayes (EB) before-after statistical analysis and an independent cross-section analysis. The findings show that the installation of wider edge lines results in reductions in several relevant crashes. These retrospective analyses, which incorporate several years of actual crash data, are considered more powerful than observational studies with a limited number of observations of driver performance.

1 INTRODUCTION

Longitudinal pavement markings provide a continuous stream of information to the road user by assisting them in selecting the appropriate lane and maintaining the appropriate lane position. This is true in both day and night conditions. It seems logical that increasing marking visibility will better enable drivers to maintain the appropriate lane position and to see and react to changes in road alignment earlier, resulting in an improvement in safety. In recent years, the use of wider pavement markings is one method by which transportation engineers have been trying to increase safety, as it is believed that wider pavement markings benefit drivers by increasing the visibility of the pavement markings.

In the United States, the Manual on Uniform Traffic Control Devices (MUTCD) defines the purpose of longitudinal pavement markings as the delineation of the vehicle path along the roadway. Variations in longitudinal markings are achieved by altering the color, pattern and width, all of which contribute to identifying the proper path for a driver (FHWA, 2003). It should be noted that while the MUTCD defines standard longitudinal pavement markings as having a width of 4 to 6 inches, for this report, any pavement markings that are wider than 4-inches have been referred to as wider pavement markings.

Across the United States, the use of 4-inch markings is the basic application, with wider lines being used when deemed necessary. As part of a study conducted in 2001 the results from a nationwide survey indicated that 58 percent (29 States) use wider pavement markings to some degree (Gates 2002). All 50 States responded to this survey, providing a solid baseline for establishing usage. The survey results also indicated that the various States’ primary reasons for the use of markings wider than 4-inches is to improve visibility and thereby improve safety.

The 2001 study also found that there is limited research on the safety effects of using wider edge line markings. The existing research does not provide conclusive results on the benefits of wider markings, and the results of various studies often conflict. Despite these inconclusive findings, a 2007 survey shows that the use of wider pavement markings in the United States is on the rise (Carlson, 2009 (2)).

This paper presents preliminary findings from an on-going study evaluating the effectiveness of wider edge lines in the United States. While there are several objectives of the study, this paper described the findings related to the safety of edge lines on two-lane highways. Under the larger study, additional work is being completed on other aspects of pavement markings, including the safety of wider edge lines on other facility types such as freeways and expressways.

More specifically, this paper summarizes the safety analysis efforts associated with various pavement marking widths on rural two-lane highways. A general description of the data collection approach is provided, followed by the results of two analyses of the data. The two analyses are a cross-sectional safety comparison of rural 2-lane segments with 5-inch edge lines to segments with 4-inch edge lines, and a before-after analysis of rural 2-lane segments on which the edge line width was changed from 4 inches to 6 inches.
2 DATA COLLECTION

An electronic survey was distributed to identify States that install pavement markings wider than 4-inches on all or some of their State-owned highways. It was sent through several different media, including:

- A list of State transportation agency representatives manually developed using rosters for American Association for State Highway and Transportation Official (AASHTO) Subcommittee on Safety Management and Subcommittee on Traffic Engineering as well as other research team contacts with pavement marking responsibilities.
- Listserv for AASHTO Subcommittee on Traffic Engineering.
- Listserv for Institute of Transportation Engineers (ITE) Traffic Engineering.
- Listserv for National Committee on Uniform Traffic Control Devices (NCUTCD) Markings Technical Committee.
- Listserv for Transportation Research Board (TRB) Traffic Control Devices Committee.

Several rounds of follow-up telephone calls were made to those States that were identified as having current or previous experience with wider lines. State traffic engineers, district traffic engineers, maintenance engineers, and staff from other safety-related agency branches were contacted to determine whether:

- Locations (by route number and linear reference) of the wider lines could be determined.
- Use of wider lines was extensive on roadway segments (i.e., not spot treatments).
- Approximate dates of wider line installation were known.
- Sufficient crash, traffic, and roadway databases existed in formats that could be merged with each other and with pavement marking information.

The convergence of affirmative answers in all four areas was rare. Required data were most readily available in Illinois and Michigan.

2.1 Illinois Data

Illinois has varying pavement marking practices across its nine districts. The minimum line width in District 6 is 5 inches. This includes edge lines on both sides of the traveled way, skip lines, and other types of centerline markings. In District 3, edge lines and centerlines are 4 inches, while white skip lines and yellow skip lines on 2-lane highways are 6 inches. The pavement marking practices date back 15-plus years, before the availability of reliable crash and roadway data for a before-after analysis. A cross-sectional analysis approach is possible using more current crash, traffic, and roadway data. Additional detail is provided in the analysis section below.

Illinois is a participating State in the Highway Safety Information System (HSIS). HSIS is a multistate database managed by the University of North Carolina Highway Safety Research Center and Lendis Corporation, under contract with FHWA. Participating HSIS States were selected based on their data quality and the ability to merge electronically coded crash- and highway infrastructure-related files. The HSIS database is often the first data alternative for highway safety research with national sponsorship and geometric design components, including research efforts associated with production of the Highway Safety Manual and Safety Analyst.

Illinois crash and roadway inventory files were obtained from HSIS for years 2001 through 2006. Crashes are located by a county, route number, and milepost. Roadway segments are defined by county, route number, beginning milepost, and ending milepost. Crashes were assigned to appropriate roadway segments and counted using a variation of Statistical
Analysis Software SAS code provided by the HSIS lab manager. Over 115 different crash type variations were originally counted. The number was reduced to the following 14 types after a number of preliminary model estimation runs and research team decisions related to the most relevant crash counts for this analysis:

1. Total number of crashes.
2. Total number of fatal plus injury (F+I) crashes.
3. Total number of property damage only (PDO) crashes.
4. Total number of day crashes.
5. Total number of night crashes.
6. Total number of fatal plus injury crashes during day.
7. Total number of fatal plus injury crashes during night.
8. Total number of wet weather crashes.
9. Total number of crashes during wet weather at night.
10. Total number of single vehicle crashes.
11. Total number of single vehicle crashes in wet weather conditions.
12. Total number of crashes with at least one driver 55 or older.
13. Total number of opposite direction crashes (includes opposite direction sideswipe and head-on collisions).
14. Total number of fixed object crashes.

Roadway segments and associated crash counts for rural two-lane highways were identified using area type and roadway classification indicators. Rural two-lane segments coded with presence of traffic signals, stop signs, or yield signs were deleted from the database to minimize the influence of intersection presence on the analysis. Additional segments coded as having extremely short segment lengths or atypical rural two-lane highway features (e.g., medians, auxiliary lanes) were also eliminated. Finally, segments that showed any change in physical features during the observation period (2001 through 2006) were deleted to try and minimize the influence of any major reconstruction project on the analysis results. The final rural 2-lane data set for Illinois consisted of 3,439 segments (1,581.2 miles): 2,810 segments (1,321.4 miles) with 4-inch edge lines and 629 segments (259.7 miles) with 5-inch edge lines. Six years of data (2001 through 2006) were available for each segment. Descriptive statistics for the primary segment variables considered in the analysis are summarized in table 1 and table 2.

### Table 1. Descriptive statistics for continuous Illinois segment variables.

<table>
<thead>
<tr>
<th>Segment variable</th>
<th>2,810 segments (1,321.4 miles) with 4-inch edge lines</th>
<th>629 segments (259.7 miles) with 5-inch edge lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (miles)</td>
<td>Minimum: 0.12 - 5.45</td>
<td>Average: 0.47</td>
</tr>
<tr>
<td>Average daily traffic (vehicles per day)</td>
<td>Minimum: 100</td>
<td>Maximum: 25,900</td>
</tr>
<tr>
<td>Daily commercial traffic (trucks per day)</td>
<td>Minimum: 0</td>
<td>Maximum: 4,500</td>
</tr>
<tr>
<td>Lane width (feet)</td>
<td>Minimum: 8</td>
<td>Maximum: 16</td>
</tr>
<tr>
<td>Shoulder width (feet)</td>
<td>Minimum: 0</td>
<td>Maximum: 14</td>
</tr>
<tr>
<td>Paved shoulder width (feet)</td>
<td>Minimum: 0</td>
<td>Maximum: 12</td>
</tr>
</tbody>
</table>
Table 2. Descriptive statistics for categorical Illinois segment variables.

<table>
<thead>
<tr>
<th>Segment variable</th>
<th>Frequency</th>
<th>Percent</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posted speed = 25 mi/h</td>
<td>1</td>
<td>&lt; 0.1</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Posted speed = 30 mi/h</td>
<td>43</td>
<td>1.5</td>
<td>16</td>
<td>2.5</td>
</tr>
<tr>
<td>Posted speed = 35 mi/h</td>
<td>80</td>
<td>2.8</td>
<td>27</td>
<td>4.3</td>
</tr>
<tr>
<td>Posted speed = 40 mi/h</td>
<td>72</td>
<td>2.6</td>
<td>14</td>
<td>2.2</td>
</tr>
<tr>
<td>Posted speed = 45 mi/h</td>
<td>116</td>
<td>4.1</td>
<td>34</td>
<td>5.4</td>
</tr>
<tr>
<td>Posted speed = 50 mi/h</td>
<td>76</td>
<td>2.7</td>
<td>8</td>
<td>1.3</td>
</tr>
<tr>
<td>Posted speed = 55 mi/h</td>
<td>2422</td>
<td>86.2</td>
<td>529</td>
<td>84.1</td>
</tr>
<tr>
<td>Presence of horizontal curve sharper than 2.5 degrees</td>
<td>223</td>
<td>7.9</td>
<td>44</td>
<td>7.0</td>
</tr>
</tbody>
</table>

2.2 Michigan Data

Michigan edge lines are currently 6 inches wide on all State-owned roadways (except for those with curb and gutter). The change was made from 4-inch edge lines on almost all of the State-owned systems during 2004. A Michigan Department of Transportation (MDOT) pavement marking engineer estimated that 6-inch lines were installed on 95 percent of applicable mileage in 2004, with the remainder installed in early 2005. A before-after analysis is possible with the timing of the change. The widespread switch from 4-inch to 6-inch edge lines minimizes the concern of selection bias or regression to the mean. However, it also does not allow a before-after analysis using comparison sites within the same State. The research team examined several comparison site alternatives. Additional detail is provided in the analysis section below.

Michigan crash data for years 2001 through 2006 were obtained from Michigan State Police, Traffic Crash Reporting Unit. MDOT provided roadway inventory files for those same years. Crashes are located by county, route number, physical reference (PR) number, and milepost. Roadway segments are defined by county, route number, physical reference number, beginning milepost, and ending milepost. Crashes were assigned to appropriate roadway segments and counted using SAS. Counts for 12 of the 14 crash types available for Illinois were also available for Michigan data analysis. Crash type 14 (see list on previous page), total numbers of fixed object crashes, were not available, and for crash type 12, total number of crashes with at least one driver 55 or older, the change in number of older drivers from the before to the after period was not known. A count for total number of single vehicle crashes during night was included in the Michigan data, which makes a total of 13 crash types analyzed for Michigan.

Roadway segments and associated crash counts for rural two-lane highways were identified using an area type indicator and a variable for total number of through lanes. Similar data screening techniques and criteria as those employed for Illinois data were used for Michigan, including those for intersections, atypical rural two-lane highway features, and observed changes in physical features during the observation period. The final rural 2-lane data set for Michigan consisted of 253 segments (851.5 miles). Each segment was observed for 3 years with 4-inch lines (2001 – 2003) and 2 years with 6-inch lines (2005 – 2006). Descriptive statistics for the primary segment variables considered in the analysis are summarized in Table 3 and table 4.
Table 3. Descriptive statistics for continuous Michigan segment variables.

<table>
<thead>
<tr>
<th>Segment variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (miles)</td>
<td>0.04</td>
<td>12.69</td>
<td>3.37</td>
</tr>
<tr>
<td>Average daily traffic – Before period</td>
<td>197</td>
<td>17,633</td>
<td>4,497</td>
</tr>
<tr>
<td>Average daily traffic – After period</td>
<td>299</td>
<td>18,597</td>
<td>4,433</td>
</tr>
<tr>
<td>Daily commercial traffic (trucks per day)</td>
<td>20</td>
<td>2,100</td>
<td>360</td>
</tr>
<tr>
<td>Lane width (feet)</td>
<td>10</td>
<td>12</td>
<td>11.5</td>
</tr>
<tr>
<td>Shoulder width (feet)</td>
<td>3</td>
<td>12</td>
<td>8.1</td>
</tr>
<tr>
<td>Paved shoulder width (feet)</td>
<td>0</td>
<td>11</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 4. Descriptive statistics for categorical Michigan segment variables.

<table>
<thead>
<tr>
<th>Segment variable</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posted speed = 25 mi/h</td>
<td>5</td>
<td>2.0</td>
</tr>
<tr>
<td>Posted speed = 30 mi/h</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Posted speed = 35 mi/h</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>Posted speed = 40 mi/h</td>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td>Posted speed = 45 mi/h</td>
<td>10</td>
<td>4.0</td>
</tr>
<tr>
<td>Posted speed = 50 mi/h</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>Posted speed = 55 mi/h</td>
<td>226</td>
<td>89.3</td>
</tr>
<tr>
<td>Level terrain</td>
<td>165</td>
<td>65.2</td>
</tr>
<tr>
<td>Rolling terrain</td>
<td>88</td>
<td>34.8</td>
</tr>
</tbody>
</table>

3 DATA ANALYSIS
Two types of analyses of Illinois and Michigan data were conducted. The first is a cross-sectional safety comparison of Illinois rural 2-lane segments with 5-inch edge lines to similar Illinois segments with 4-inch edge lines. The second is a before-after analysis of Michigan rural 2-lane segments on which the edge line width was changed from 4 inches to 6 inches in the year 2004.

3.1 Cross-Sectional Analysis of Illinois Data
In Illinois, data screening reduced the rural 2-lane data set to 3,439 segments (1,581.2 miles) consisting of 2,810 segments (1,321.4 miles) with 4-inch edge lines and 629 segments (259.7 miles) with 5-inch edge lines. Crashes occurring at the segments with 4-inch edge lines were
compared to crashes occurring at the segments with 5-inch edge lines. Types of crashes analyzed were: total, fatal and injury, Property Damage Only (PDO), daytime, nighttime, daytime fatal and injury, nighttime fatal and injury, wet, wet-night, single vehicle, single vehicle-wet, older-driver (>=55 years old), opposite direction (head on and sideswipe opposite direction), and fixed object crashes. Table 5 shows the average crash rates computed as crashes per million vehicle miles of travel averaged over the segments considered in the study.

Table 5. Average crash rate (in million entering vehicles) per 1-mile segment of each roadway type categorized by edge line width for Illinois rural two-lane highways.

<table>
<thead>
<tr>
<th>Edge line width</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td># of segments</td>
<td>2,810</td>
<td>629</td>
</tr>
<tr>
<td>Total segment length (mile)</td>
<td>1,321.4</td>
<td>259.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.76</td>
<td>0.44</td>
<td>1.32</td>
<td>0.74</td>
<td>0.87</td>
<td>0.26</td>
<td>0.15</td>
<td>0.19</td>
<td>0.10</td>
<td>1.31</td>
<td>0.14</td>
<td>0.79</td>
<td>0.40</td>
<td>0.04</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>1.86</td>
<td>0.33</td>
<td>1.53</td>
<td>0.64</td>
<td>0.98</td>
<td>0.19</td>
<td>0.13</td>
<td>0.14</td>
<td>0.08</td>
<td>1.55</td>
<td>0.12</td>
<td>0.94</td>
<td>0.38</td>
<td>0.05</td>
<td>0.30</td>
</tr>
</tbody>
</table>

The crash rates shown in table 5 might be useful if all the segments included in the study are identical except for edge line width, segment length, and traffic volumes (AADT), and also crashes increase linearly with AADT. However, the road segments are different not only in edge line width, segment length, and AADT, but also in other roadway characteristics such as lane width, shoulder width, presence of curves, etcetera, and the relationship between crashes and AADT is not necessarily linear. As a result, the effects of edge line width may not be estimated correctly by the differences in simple crash rates between 4-inch edge line and 5-inch edge line segments shown in table 5.

In order to separate out the effect of edge line width from other important roadway characteristics, a negative binomial regression model was developed from the data. The general form of the expected number of crashes in a negative binomial regression model can be given as follows in **Equation 1**:

\[ \mu_i = \exp(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik}) \]

where \( \mu_i \) is the expected number of crashes at segment \( i \), \( X_{i1}, \ldots, X_{ki} \) are the covariates/predictors corresponding to roadway characteristics of segment \( i \), and \( \beta_0, \beta_1, \beta_2, \ldots, \beta_k \) are the regression coefficients. A model that included edge line width, lane width, shoulder width, presence of horizontal curve (1: present, 0: not present), and log of AADT, as predictors and the log of the segment length as an offset variable provided the closest fit to the Illinois data.
Table 6 shows the estimates of the negative binomial regression model coefficients. The regression coefficient for edge line width was negative and statistically significant at $\alpha = 0.05$, which indicates a positive safety effect of wider edge lines (i.e., a smaller number of crashes is associated with wider edge lines) for the following crash types: fatal and injury (-0.3555), daytime (-0.1710), daytime fatal and injury (-0.3684), nighttime fatal and injury (-0.2900), wet (-0.2953), single vehicle wet (-0.2560), and fixed object crashes (-0.2808). It can also be observed that the signs of the coefficients for lane width, shoulder width, log of annual average daily traffic (AADT), and curve presence are consistent with intuition. For example, the negative signs of lane width and shoulder width coefficients imply that crashes tend to decrease as lane width or shoulder width increases, and the positive sign of curve presence implies that crashes tend to increase when there is a curve or curves as compared to when there is no curve.


<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Intercept</th>
<th>Edge Line Width</th>
<th>Lane Width</th>
<th>Shoulder Width</th>
<th>Log AADT</th>
<th>Curve Presence</th>
<th>Dispersion</th>
<th>Pearson Chi-Square/ DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>-5.3007</td>
<td>-0.0398</td>
<td>-0.0675</td>
<td>-0.0133</td>
<td>0.8645</td>
<td>0.2521</td>
<td>0.4288</td>
<td>1.3101</td>
</tr>
<tr>
<td>Fatal injury</td>
<td>-5.9759</td>
<td>-0.3555</td>
<td>-0.0882</td>
<td>-0.0417</td>
<td>0.9748</td>
<td>0.6070</td>
<td>0.5978</td>
<td>1.2853</td>
</tr>
<tr>
<td>PDO</td>
<td>-5.8323</td>
<td>0.0397</td>
<td>-0.0633</td>
<td>-0.0066</td>
<td>0.8458</td>
<td>0.1260</td>
<td>0.4501</td>
<td>1.2267</td>
</tr>
<tr>
<td>Daytime</td>
<td>-7.3511</td>
<td>-0.1710</td>
<td>-0.1026</td>
<td>-0.0359</td>
<td>1.1449</td>
<td>0.2547</td>
<td>0.5737</td>
<td>1.4866</td>
</tr>
<tr>
<td>Nighttime</td>
<td>-4.8929</td>
<td>-0.0239</td>
<td>-0.0475</td>
<td>-0.0014</td>
<td>0.6752</td>
<td>0.2945</td>
<td>0.4196</td>
<td>1.1137</td>
</tr>
<tr>
<td>Daytime fatal injury</td>
<td>-7.5377</td>
<td>-0.3684</td>
<td>-0.0885</td>
<td>-0.0471</td>
<td>1.1190</td>
<td>0.3579</td>
<td>0.8243</td>
<td>1.3217</td>
</tr>
<tr>
<td>Nighttime fatal injury</td>
<td>-5.7133</td>
<td>-0.2900</td>
<td>-0.0845</td>
<td>-0.0369</td>
<td>0.7619</td>
<td>0.9276</td>
<td>0.3630</td>
<td>1.0843</td>
</tr>
<tr>
<td>Wet</td>
<td>-7.2627</td>
<td>-0.2953</td>
<td>-0.0849</td>
<td>-0.0212</td>
<td>0.9853</td>
<td>0.3638</td>
<td>0.7133</td>
<td>1.1082</td>
</tr>
<tr>
<td>Wet night</td>
<td>-6.7358</td>
<td>-0.2458</td>
<td>-0.0552</td>
<td>-0.0023</td>
<td>0.7465</td>
<td>0.4562</td>
<td>0.6720</td>
<td>1.1026</td>
</tr>
<tr>
<td>Single vehicle</td>
<td>-3.6780</td>
<td>-0.0196</td>
<td>-0.0403</td>
<td>-0.0076</td>
<td>0.5624</td>
<td>0.3590</td>
<td>0.4031</td>
<td>1.1220</td>
</tr>
<tr>
<td>Single vehicle wet</td>
<td>-5.1418</td>
<td>-0.2560</td>
<td>-0.0337</td>
<td>-0.0175</td>
<td>0.5767</td>
<td>0.5359</td>
<td>0.7081</td>
<td>1.0961</td>
</tr>
<tr>
<td>Older-driver (55 years-old or older)</td>
<td>-7.4711</td>
<td>-0.0940</td>
<td>-0.0525</td>
<td>-0.0176</td>
<td>0.9571</td>
<td>0.1654</td>
<td>0.5371</td>
<td>1.3095</td>
</tr>
<tr>
<td>Opposite direction</td>
<td>-14.7025</td>
<td>0.1768*</td>
<td>-0.1019</td>
<td>-0.0051</td>
<td>1.5046</td>
<td>0.6268</td>
<td>0.3489</td>
<td>1.1148</td>
</tr>
<tr>
<td>Fixed object</td>
<td>-5.0044</td>
<td>-0.2808</td>
<td>-0.0216</td>
<td>-0.0651</td>
<td>0.6937</td>
<td>0.6994</td>
<td>0.5051</td>
<td>1.2885</td>
</tr>
</tbody>
</table>

Notes: 1. Significant (at $\alpha = 0.05$) effects are shown in bold; 2. There was an extreme outlier in the Opposite Direction crash data for a 0.27 mile segment with 3-inch edge lines, which greatly affected an estimate of the edge line width coefficient for Opposite Direction crashes. When this outlier was removed, the Opposite Direction coefficient for Edge Line Width changed from 0.3295 to 0.1768 and became insignificant.
For Illinois, raised reflective pavement markings (RRPMs) are used statewide, and rumble strips are used on interstates statewide. It needs to be noted, however, that the information on additional delineation and guidance measures (other than RRPMs and rumble strips) was not available and could not be incorporated into the analysis. Therefore, the above observations are based on the assumption that the effects of the variables not in the database such as those additional delineation/guidance measures are the same (or averaged out) for the segments with and without wider edge lines.

3.2 Before-After Analysis of Michigan Data
In Michigan, changes to 6-inch edge lines occurred in 2004 for about 95 percent of road segments statewide. Before-after evaluations were conducted with 3 years (2001~2003) of before and 2 years (2005~2006) of after data obtained from 253 segments corresponding to 851.5 miles of rural two-lane highways. Crashes that occurred during the before period were compared to crashes that occurred during the after period. Types of crashes analyzed were: total, fatal and injury, PDO, daytime, nighttime, daytime fatal and injury, nighttime fatal and injury, wet, wet-night, single vehicle, single vehicle-wet, single vehicle night, and opposite direction (head on and sideswipe opposite direction). Table 7 shows the average crash rates computed as crashes per million vehicle miles of travel averaged over the segments considered in the study for each of the before and after periods.

Table 7. Average crash rate (in million entering vehicles) per 1-mile segment of Michigan rural two-lane highways for each of before (2001~2003) and after (2005~2006) periods.

<table>
<thead>
<tr>
<th>Number of segments</th>
<th>253</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total segment length</td>
<td>851.5</td>
</tr>
<tr>
<td>Period</td>
<td>Before</td>
</tr>
<tr>
<td>Crash Type</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3.06</td>
</tr>
<tr>
<td>Fatal Injury</td>
<td>0.44</td>
</tr>
<tr>
<td>PDO</td>
<td>2.63</td>
</tr>
<tr>
<td>Daytime</td>
<td>1.29</td>
</tr>
<tr>
<td>Nighttime</td>
<td>1.41</td>
</tr>
<tr>
<td>Daytime Fatal Injury</td>
<td>0.29</td>
</tr>
<tr>
<td>Nighttime Fatal Injury</td>
<td>0.12</td>
</tr>
<tr>
<td>Wet</td>
<td>0.28</td>
</tr>
<tr>
<td>Wet Night</td>
<td>0.14</td>
</tr>
<tr>
<td>Single Vehicle</td>
<td>2.26</td>
</tr>
<tr>
<td>Single Vehicle Wet</td>
<td>0.21</td>
</tr>
<tr>
<td>Single Vehicle Night</td>
<td>1.29</td>
</tr>
<tr>
<td>Opposite Direction</td>
<td>0.08</td>
</tr>
</tbody>
</table>

It can be observed from table 7 that crash rates decreased overall. However, this direct comparison of before and after crash rates is valid only when it can be absolutely assured that there have been no changes from before to after periods other than edge line width and traffic volumes and that the relationship between crashes and traffic volumes is linear. As a matter of fact, both of these assumptions are often violated when the crash data of multiple years are analyzed. There will almost always be changes over time in weather, vehicle fleet, driver characteristics, economic conditions, etc., and crashes may increase with traffic volume in a non-linear fashion.

To distinguish the effect of edge line width from the effects of other factors that might have also changed from the before to the after period, an advanced statistical before-after evaluation method known as the empirical Bayes approach for safety evaluation was
employed (Hauer 1997). The empirical Bayes method estimates changes in crashes (due to wider edge lines) by comparing the observed number of after period crashes to the predicted number of crashes during the after period that would have occurred had wider edge lines not been installed, rather than to the observed number of before period crashes. Predicted crash frequencies by the empirical Bayes method are obtained in such a way that they account for a potential non-linear relationship between crashes and traffic volume (through the regression function called the Safety Performance Function [SPF]) as well as changes in general underlying trend caused by extraneous factors such as weather, vehicle fleet, driver characteristics, etcetera, between the before and after periods. The SPF, which describes the relationship between crashes and traffic volume as well as other roadway characteristic variables such as lane width, shoulder width, terrain, etcetera, were derived from the before-period Michigan data. The changes in general trend would typically have been estimated based on crash counts from road segments on which edge line width remains at 4 inches throughout the study period. Because no such segments remained in Michigan, due to statewide installation of 6-inch edge lines during the study period, an alternative approach of deriving the trend factor based on another entity set was taken in which the general trend between the before and after periods was derived from the Illinois fatal and injury crash data obtained from rural 2-lane segments with 4-inch edge lines (Persaud 2007). Using the Illinois data to provide a comparison group yielded results that are comparable to the cross-sectional analysis conducted with the Illinois data. Additional analyses are being conducted to further verify this approach.

Table 8 presents the result of empirical Bayes before-after evaluations based on the crash data from 253 segments (851.5 miles) of Michigan rural 2-lane highways. The observed number of after crashes over 253 segments, the predicted number of crashes during the after period that would have occurred without installing wider edge lines, and an estimate of the percent change in crashes from the before to the after period are shown in the table. As can be observed from the table, for rural two-lane highways in Michigan, the empirical Bayes before-after evaluations (using the before period Michigan data to develop the Safety Performance Functions and the Illinois fatal and injury crash data obtained from segments with 4-inch edge lines to derive a trend between the before and after periods) resulted in the following crash reduction estimates:

- Total crashes – 7.1 percent.
- Fatal and injury crashes – 17.1 percent.
- PDO crashes – 5.4 percent.
- Daytime crashes – 10.0 percent.
- Nighttime crashes – 2.4 percent.
- Daytime fatal and injury crashes – 18.0 percent.
- Nighttime fatal and injury crashes – 11.7 percent.
- Wet crashes – 24.4 percent.
- Wet night crashes – 22.6 percent.
- Single vehicle crashes – 2.0 percent.
- Single vehicle wet crashes – 20.0 percent.
- Single vehicle night crashes – -0.2 percent.
- Opposite direction crashes – 14.9 percent.

All of these crash reduction estimates, except for nighttime, single-vehicle, and single-vehicle night crashes, were statistically significant at the 95 percent level.
Table 8. Results of empirical Bayes before-after safety evaluations based on the Michigan crash data with 3 years (2001–2003) of before and 2 years (2005–2006) of after data obtained from 253 segments (851.5 miles) of rural two-lane highways.

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Observed After Crashes</th>
<th>Predicted After Crashes with 4 inch Edge Lines</th>
<th>Percent Reduction in Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>6,077</td>
<td>6,541.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Fatal Injury</td>
<td>811</td>
<td>977.5</td>
<td>17.1</td>
</tr>
<tr>
<td>PDO</td>
<td>5,266</td>
<td>5,563.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Day</td>
<td>2,231</td>
<td>2,478.6</td>
<td>10.0</td>
</tr>
<tr>
<td>Night</td>
<td>3,149</td>
<td>3,277.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Daytime Fatal Injury</td>
<td>498</td>
<td>607.1</td>
<td>18.0</td>
</tr>
<tr>
<td>Nighttime Fatal Injury</td>
<td>257</td>
<td>291.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Wet</td>
<td>459</td>
<td>607.1</td>
<td>24.4</td>
</tr>
<tr>
<td>Wet Night</td>
<td>243</td>
<td>313.7</td>
<td>22.6</td>
</tr>
<tr>
<td>Single Vehicle</td>
<td>4,862</td>
<td>4,962.86</td>
<td>2.0</td>
</tr>
<tr>
<td>Single Vehicle Wet</td>
<td>353</td>
<td>440.691</td>
<td>20.0</td>
</tr>
<tr>
<td>Single Vehicle Night</td>
<td>2,923</td>
<td>2,916.34</td>
<td>-0.2</td>
</tr>
<tr>
<td>Opposite Direction</td>
<td>165</td>
<td>193.8</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Note: Statistically significant results (at 95% confidence level) are shown in bold.

4 SUMMARY
The retrospective crash analysis based on Illinois and Michigan rural two-lane highway data shows that there are positive safety effects of wider markings for relevant crashes.

- For Illinois, the negative binomial regression analysis based on the crash data aggregated for six years resulted in positive safety effect estimates for fatal and injury, daytime, daytime fatal and injury, nighttime fatal and injury, wet, single vehicle wet, and fixed object crashes.
- For Michigan, an empirical Bayes before-after evaluation resulted in positive safety effect estimates for total, fatal and injury, PDO, daytime, daytime fatal and injury, nighttime fatal and injury, wet, wet night, single vehicle wet, and opposite direction crashes.

It should be noted that additional work is being completed. For the retrospective crash analysis, the researchers are analyzing the impacts of widening Interstate Highway markings from 4 to 6 inches. For the crash surrogate study, the researchers are conducting a more thorough statistical analysis using multivariate analyses techniques.

REFERENCES
American Association of State Highway and Transportation Officials Web Site. 
Implementing the AASHTO Strategic Highway Safety Plan. Obtained from: 
Carlson, P.J., Park, E.S., and Andersen, C.K. (2009). The Benefits of Pavement Markings: 
A Renewed Perspective Based on Recent and Ongoing Research. TRB DVD Compendium of 
Papers. TRB Annual Meeting. Washington, DC, USA.
Carlson, P.J., E.S. Park, C.K. Andersen, B. Kuhn, A. Pike, J. Miles, R. Brydia, W. Ealding,
of Tennessee: Report to Congress. U.S. Department of Transportation, Federal Highway 
Administration, Report Number FHWA-HRT-09-039, McLean, VA.
College Station, TX.
Effect of Highway and Traffic Engineering Measures on Road Safety. Pergamon Press, 
Learned from Two Decades of Experience and Future Directions.” Accident Analysis & 
Prevention, (39), 546–555.
A SIMULATION-BASED TRAFFIC SAFETY EVALUATION OF SIGNALIZED AND UN-SIGNALIZED INTERSECTIONS

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ABSTRACT
In many cases, crashes at intersections account for over 50% of all urban road accidents. The need to reduce these crashes has fostered considerable research on the development and evaluation of traffic safety at intersections. This paper introduces a micro-level behavioral method for estimating crash potential at signalized and unsignalized intersections for different traffic characteristics. As long as Speeding is recognized as a major contributing factor in traffic crashes, in this study it is emphasized on the contribution of speed in traffic safety situation of intersections. In this study, proximal safety indicators which represent the temporal and spatial proximity characteristics of unsafe interactions and near-accidents are explored and then one of them is implemented in the safety evaluation process for unsignalized intersections and time headway for signalized intersections as a flow characteristic. Results show that an increase of speed limit on roads will end to a more dangerous situation. On the other hand the ability of microsimulator to evaluate safety effects of such policy measure like speed limit is proven.

1 INTRODUCTION
Intersections present special safety concerns because of unsafe driver actions and maneuvers that result in traffic conflicts with a potential for preventable crashes. These include conflicts in vehicle trajectories for different intersection approaches, pedestrian conflicts, abrupt changes in vehicle speeds, unexpected lane changes, etc. A number of recent studies of crashes for North American urban roads suggest that over 50% of reported road crashes take place in proximity to intersections [1].

Speeding is recognized as a major contributing factor in traffic crashes, specifically for intersections. Numerous studies have been conducted to elucidate the relationship between speed and safety: detailed reviews of which are provided elsewhere [2, 3]. Three of the most important elements of this study were (a) controls for speed conditions in models of crash counts, (b) use of disaggregate roadway data permitting tight control of design factors, and (c) specification and evaluation of various count models for panel data. The results of several studies that examine the effect of speed enforcement programs on safety and speed have confirmed that it is evident that a driver’s speed is one of the most important factors affecting crash severity, owing to the relationship between vehicle velocity, kinetic energy, and energy absorption upon impact. The studies in general show that speed enforcement programs lead to a significant reduction in speed and crash frequency. Several studies solely evaluated the effect of speed enforcement on speed...
or on traffic safety [6, 7], while others evaluated both speed and safety [8-13]. In an evaluation study, the effects on mean speed, the percentage of speed limit violators, the number of injury accidents, and the number of serious casualties were assessed by comparing the development on the roads that were subject to targeted speed enforcement with the development on similar roads without targeted enforcement. Both the mean speed and the percentage of speed limit violators decreased during the targeted enforcement program [12]. Another research presents the results of a comprehensive analysis of the impact of the speed enforcement program on speeding behavior, crashes, and the economic impact of crashes. The impact on speeding behavior was estimated using generalized least square estimation, in which the observed speeds and the speeding frequencies during the program period were compared to those during other periods [13].

On the other hand the relationship between traffic flow and traffic safety should be considered. Benedetto et al. [14] verified the variability of probability and severity of accident for different traffic flows.

Experience shows that microscopic traffic simulation is able to improve the knowledge of risks within a traffic flow. Thus, microsimulation can contribute to better road safety. In fact, microscopic traffic simulation helps to evaluate and optimize different routing strategies, without having to realize tests in the field. These tools are mainly used to estimate the performance level of road networks in terms of flow, speed or travel time. The possibilities offered by these software tools, in order to estimate the safety level, remain however limited. In a related research a new safety indicator is proposed which is called “unsafety density” (UD). The concept of the unsafety parameter is based on the direct interaction between couple of vehicles, which seem to be appropriate for treating safety problems. The UD parameter takes into account only potential for rear-end collision and is therefore particularly planned for highways network assessments. This indicator allows highlighting the difference in safety level between a fluid and a congested traffic flow situation, which cannot be shown by using traditional macroscopic outputs like speed, flow or occupancy [15, 16]. In another study a new microsimulator was developed, called “ValSim”, which allows researchers to relate the skewed angle at intersections (merging or crossing) to the driver’s angle of visibility for both direct vision and indirect vision through rearview mirrors. Thus, it is possible to evaluate road safety. ValSim aims to allow designers to evaluate, by dynamical analysis in the geometric design process, the configuration and geometry of an intersection, and to verify possible conflicts at merging as well as at skewed crossings due to lack of visibility. The software simulates the driver's behavior while carrying out the entry or crossing maneuver. For each moment, it calculates the blind spot zones and a possible visibility conflict is highlighted [16].

The potential benefits of adopting a micro-level simulation approach were initially recognized by Darzentas et al. [17]. Although the use of micro-level simulation in safety work has found some resistance due to the inherent problems of accurately representing a complex crash situation, which may require a more comprehensive in-depth “Nanosopic” view of the various relationships involved [18]. This can require a great amount of computer power and capacity. Researchers have attempted to overcome these limitations by using surrogate safety measures within the context of a more aggregate micro-level approach. Arguably, it is a more effective safety assessment strategy which involves the use of proximal safety indicators that represent the temporal and spatial proximity characteristics of unsafe interactions and near-accidents. The main advantage of such measures is related to their resource-effectiveness given that they occur more frequently than accidents and require relatively short periods of observation in order to establish statistically reliable results. Such surrogate measures include, time-to-collision (TTC), time...
extended TTC (TET), post-encroachment time (PET) and deceleration rate (DR), etc. [19, 20, 15, and 21]. Gettman and Head described a project which has identified surrogate measures that can be collected from commercial simulation models for evaluation of the relative safety of intersection design alternatives or existing facilities. It was pointed out in their study that the surrogate indicators that are proposed as the best measures are TTC, PET, and DR. It was emphasized that TTC, PET, and DR can be used to measure the severity of the conflict [20]. Mouzon et al. have reported a study carried out for assessing risk associated to traffic situations through surrogate safety indicators. The findings show that these safety indicators are able to react before most of the accident occurrences [21].

Recently, a procedure is presented for calibrating and validating a microscopic model of safety performance at signalized intersections, using the above mentioned indicators [22]. In this research a systematic procedure is presented for calibrating and validating a microscopic model of safety performance. The context in the model application is the potential for rear-end crashes at signalized intersections.

2 METHODOLOGY

In this research, two different safety indicators are used to evaluate safety situation at signalized and unsignalized intersections. For signalized intersections, time headway as a safety indicator which can be obtained easily is chosen. Time headway is one of the indicators that are used to estimate the criticality of a certain traffic situation. It has been defined as the elapsed time between the front of the lead vehicle passing a point on the roadway and the front of the following vehicle passing the same point. Time headway is measured by taking the time that passes between two vehicles’ reaching the same location. Different countries have slightly different rules with regard to the legal or recommended safety distance. In the US, e.g. several drivers training programs state that it is impossible to follow a vehicle safely with headway of less than 2 sec [23]. In Sweden the National Road Administration recommends time headway of 3 sec in rural areas, and the police use time headway of 1 sec as orientation for imposing fines. In Germany, the recommended minimum distance is “half the speedometer”, which means a car traveling at 80 km/hr should keep a distance of at least 40 m. This rule translates to a recommended time headway of 1.8 sec. Fines are imposed when the time headway is smaller than 0.9 sec [24]. There are several other safety indicators, have been used for safety evaluation studies which were discussed about above. For instance, TTC is a very promising indicator for such purposes but the difficulty in its computation process brought us to this conclusion that time headway is a useful, easy to obtain and meaningful indicator. In a comparative research, Vogel [24] recommended that authorities use headway as criterion for tailgating, because it is easy to measure, it is easily understandable and interpretable, and most important of all, it is directed against potential danger, which effectively prevents dangerous TTC values from occurring at all. On the other hand, by defining a safety threshold for headway, it is possible to purify and filter the data in order to avoid too much work on the procedure of TTC calculation. In a car-following situation (e.g. vehicles are approaching a signalized intersection and rear-end accident may have occurred) TTC can never be smaller than the time gap between the lead and the following vehicle. Thus, if the two values are to be compared, it seems reasonable to keep out the cases that are not safety critical with respect to any of the two measures. In other words, for large values of headway, having small TTCs is impossible and having a TTC value bigger than the headway is not unsafe. As a result, sifting the data according to the headway critical threshold will help in reducing computational works. Therefore a short headway can be interpreted as potential danger,
because only vehicles that travel with short headways have the possibility to produce small TTC values and then causing accidents.

In this research a microsimulator (S-Paramics) is applied to investigate whether changing speed limits under different traffic volume categories will affect traffic safety or not. Different simulations were done at different traffic volume and speed limit categories in order to make the survey as comprehensive as possible.

Headway is one of the outputs of the simulator. To achieve headways of all vehicles on different approaches, several different loop detectors are defined on the network to collect the needed data.

While the use of statistical models based on historical accident data are most common in traffic engineering today, there are availability and quality problems associated with the data on which they are based. This approach is also considered “reactive” in nature rather than “proactive”, where a significant number of accidents must occur before the problem is identified and suitable corrective measures are implemented. Understanding these problems, researchers have recently proposed a framework for “proactive” safety planning, i.e. planning that is not entirely based on historical accident data, but uses other measures such as the use of safety indicators and predictive models [25].

An alternative and/or complementary approach to safety prediction is to measure the more frequent occurrence of near-accidents using proximal safety indicators where these are believed to have an established relationship to accident occurrence. Proximal safety indicators have been suggested as an alternative to the use of accident data. These are defined as measures of accident proximity, based on the temporal and/or spatial measures that reflect the “closeness” of road-users (or their vehicles), in relation to projected point of collision. The actual measure of accident proximity depends on the safety indicator concept or technique used.

A key advantage (and prerequisite) of proximal safety indicators is that they occur considerably more frequently than accidents. This suggests the need for a significantly shorter study period to establish statistically reliable results. Furthermore, the use of proximal safety indicators is also a more resource-efficient and ethically appealing alternative for fast, reliable and effective safety assessment.

A number of related criteria that can be used to identify the usefulness of proximal safety indicators have been identified, suggesting that they must [25]:

1. Complement accident data and be more frequent than accidents
2. Have a statistical and causal relationship to accidents
3. Have the characteristics of ‘near-accidents’ in a hierarchical continuum that describes all severity levels of road-user interactions with accidents at the highest level and very safe passages with a minimum of interaction at the lowest level

There is several number of proximal safety indicators like TTC, Time Integrated TTC (TIT), TET, PET, Time-to-Zebra (TTZ), DR, Deceleration-to-Safety Time (DST), Proportion of Stopping Distance (PSD), Shock-Wave Frequency, Time-to-Line Crossing (TLC) and Standard Deviation of Lateral Position (SDLP) which have been applied recently in different studies.

For the current research PET, as one of the most common used proximal safety indicators in the literature, is chosen to evaluate the safety situation of unsignalized intersections. This measure is used to evaluate situations in which two road-users that are on a collision course, pass over a common spatial point or area with a temporal difference that is below a predetermined threshold. The measure represents the difference in time between the passages of the “offended” and “conflicted” road-users over a common conflict zone (i.e. area of potential collision). This
makes PET not only a useful ‘objective’ measure, but also one that is less resource-demanding than TTC with regard to data-extraction process, not requiring constant recalculations at each time-step during a safety critical event [25]. An example representing the calculation of Post-Encroachment Time is illustrated below in Figures 1(a) and 1(b). The example shown below indicates the position of the two vehicles involved in the safety critical event at the start and end of the PET measurement.

![Figure 1: (a) and (b): Example of the calculation of a Post-Encroachment Time event [25]](image)

Outputs of the microsimulator don’t provide any direct data about safety situation so a procedure should be adopted to derive desired safety measures out of the output files. To do this, four loop detectors are defined on outgoing links of the four approaches of the intersection. The detectors are located after the conflict zones; so PET values are easy to be obtained. These detectors will collect needed data such as speed and position of each vehicle. In the context of traffic safety evaluation, data should be as precisely as possible. This issue will become clearer if take it into account that all conflict events will usually take place in less 2 or 3 seconds. To do so, simulation rate is defined at 10 steps per second. It means that all the required data is gathered and available for each tenth of a second.

To simplify the process of PET computation, four different conflict zones are assumed and defined for each intersection on which all of the possible conflicts will occur. These four
different conflict zones at a 4-leg intersection are depicted in Figure 2. Also it is assumed that each roadway on each direction contains 2 lanes.

![Image of a 4-leg intersection with conflict zones and traffic directions]

Figure 2: conflict zones at intersection and traffic directions.

3 SIMULATION RESULTS

The main objective of this paper is to evaluate the safety condition of signalized and unsignalized 4-leg intersection under different traffic characteristics. One of the major concerns for evaluating traffic safety at intersections is speed limit on different roadways.

Different scenarios based on different speed limits and traffic flow demands, are implemented for a comprehensive study. Traffic volume measures are suggested in a way not to have any kind of traffic congestion. Obviously a situation like traffic jam, drivers’ behavior is not the same as normal situation. On the other hand in traffic congestion situation, vehicles will not drive at their desired speed; thus, evaluating the safety performance at different speed limits will be infeasible.

For the signalized intersection which is implemented in this simulation, has traffic volume on major roads is assumed to vary from 750 vehicles per hour (vph) to 2000 vph and on minor roads is supposed to be from 350 vph to 1000 vph. Also speed limits are assumed to vary from 45 kilometers per hour (km/hr) to 85 km/hr on major roads and on minor roads from 35 km/hr to 60 km/hr.

Analyzing the results, shows a significant different in headway distribution at different levels of speed limits. When drivers drive faster, distribution at low values of headway is denser. This fact indicates that a higher speed limit which actually ends to a higher level of operating speed will produce smaller values of headway which is more dangerous in terms of traffic safety. However, the mean value of headway for all speed limits will be approximately constant, if there is no change in traffic demand, because the mean time headway is just depended on traffic flow.

Figure 3 depicted a “Density Estimate Distribution” of one scenario with the flow rate of 1000 vph for major road. In order to have a better view, the distribution graph is limited to 3 seconds. As it is shown, the distribution for highest speed limit is the densest for small values of headway.
and vice versa. It means that at high speeds, simulated values of headway are smaller than lower speed limit situations.

![Density Estimates of Headway Distribution](image)

Figure 3: Density estimates of headway distribution for 1000 vph on major road.

The unsignalized intersection which is put into practice is presumed to be a two way stop control intersection. Therefore, vehicles on major roads have the priority and vehicles on minor road have to stop at the stop line. As it was discussed above, traffic demand should be in a way to avoid traffic congestion. Different simulation runs were done to evaluate the upper limit of traffic demand with respect to speed limit on both major and minor road. Based on the results of this simulation runs traffic volume on major roads is assumed to vary from 500 vehicles per hour (vph) to 650 vph and on minor roads is supposed to be from 150 vph to 250 vph.

On the other hand speed limits are assumed to vary from 45 kilometers per hour (km/hr) to 75 km/hr for major roads and on minor roads from 35 km/hr to 50 km/hr.

At these volume levels and speed limits no traffic congestion was seen and vehicles were driven at their desire speed; so the output data is reliable and not affected by other parameters.

In order to assess the impact of variable speed limits, each scenario is compared with the others at the same level of traffic volume. Because the simulator assigns traffic demand stochastically, to avoid any probable misinterpretation, simulation has been carried out 10 times for each scenario and the mean values of PET were calculated.

Analyzing the results indicates that there is a significant change in traffic safety condition in terms of PET values. It was turned out that by increasing speed limits on both roadways, mean values of PET will decrease. It means that in such situations which drivers are driving faster on the major roadway, drivers on the minor roadway will accept a smaller gap to cross over the intersection and PET, as a proximal traffic safety indicator, specifies a worse safety situation at higher levels of speed limit.
Furthermore, it was found that increasing the traffic volume on both major and minor roadways, will conduce to a decrease of mean PET values. It might be interpreted that the traffic safety situation will become worse by increasing traffic volume as long as no traffic congestion has happened. Arguably at the higher level of traffic demand, vehicles on major roads will face more conflicting vehicles from minor roads on conflict zones. On the other hand vehicles on minor roads have to cross over the intersection, accepting shorter gap times because of more traffic on major roads. By increasing traffic volume, probability of finding large gap times becomes less and consequently PET values will become shorter as well.

Mean values of PET are shown in Table 1 regarding the speed limits and traffic volume on major and minor roads. Also for a better comprehension, a “Density Estimate Distribution” of one scenario (Maj=500 vph, Min=150 vph) is depicted in Figure 4. As it is shown, the distribution for highest speed limit is the densest for small values of PET and vice versa. It means that at high speeds, simulated values of PET are smaller than lower speed limit situations.

Table 1: Mean PET values for different speed and traffic situations.

<table>
<thead>
<tr>
<th>Volume/Speed</th>
<th>Maj=45 km/hr</th>
<th>Maj=55 km/hr</th>
<th>Maj=65 km/hr</th>
<th>Maj=75 km/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maj=650 vph, Min=250 vph</td>
<td>23.6629</td>
<td>21.1768</td>
<td>20.7834</td>
<td>19.7155</td>
</tr>
<tr>
<td>Maj=600 vph, Min=200 vph</td>
<td>24.387</td>
<td>22.7361</td>
<td>21.4859</td>
<td>20.1545</td>
</tr>
<tr>
<td>Maj=600 vph, Min=150 vph</td>
<td>28.23</td>
<td>26.4424</td>
<td>24.7612</td>
<td>24.226</td>
</tr>
<tr>
<td>Maj=550 vph, Min=200 vph</td>
<td>24.2051</td>
<td>22.8496</td>
<td>22.6376</td>
<td>21.5428</td>
</tr>
<tr>
<td>Maj=550 vph, Min=150 vph</td>
<td>29.0857</td>
<td>26.4458</td>
<td>25.846</td>
<td>24.9584</td>
</tr>
<tr>
<td>Maj=500 vph, Min=200 vph</td>
<td>22.1836</td>
<td>21.8768</td>
<td>21.0508</td>
<td>20.1744</td>
</tr>
<tr>
<td>Maj=500 vph, Min=150 vph</td>
<td>25.8352</td>
<td>24.8912</td>
<td>23.9772</td>
<td>23.3489</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND FUTURE RESEARCH

This paper presented a safety evaluation of signalized and unsignalized intersections using microsimulation, headway; a flow characteristic and proximal safety indicators. Applying time headway offers a safety evaluation of signalized intersection, while implementing PET as a safety indicator provides useful comparisons for evaluating safety conditions at unsignalized intersection with in different scenarios based on dissimilar traffic volume and speed limit categories.

In this research the practical merits of microsimulation is demonstrated with varying traffic volumes and speed limits on major and minor roads. The application shows how changes in speed limits and also traffic volume will affect safety situation.

Results indicated that increasing in speed limits on both roadways will deteriorate safety situation. This will be more obvious for higher ranges of traffic volumes. On the other hand increasing traffic volume, up to the range that doesn’t cause any traffic congestion, will worsen safety situation. Mean values of PET will be decreased by increasing speed limits and also traffic volumes. Also at higher speeds on the roadways, approaching a signalized intersection, number of observed short headways is more than lower speed limit situations. It means that speeding will make the traffic safety situation worse.

This study also shows that drivers’ behaviors which have been defined in the microsimulator “S-Paramics” is sensitive to changes in speed limits as a policy measure. Nonetheless it is still like a black box that how changing in speed limit or traffic demand will affect drivers’ behavior and other inter-models like car following models used in the simulator.
This study’s promising results pointed out the opportunity of expanding the research to a more complex, comprehensive and extensive traffic safety evaluation including other traffic policy measures.

Although it is necessary to point out that this study does not cover all of the most often used traffic safety proximal indicators like TTC and its derived sub-indicators such as Time Integrated Time-to-collision and Time Exposed Time-to-collision. TTC and its resultant indicators could be used to investigate many types of collisions like transverse, rear-end and converging collisions, while PET can just explore transverse collisions. Nevertheless, besides the simple procedure of calculating PET and its great indication of safety situation, authors believe that this safety indicators yields promising results for a safety evaluation, specifically for unsignalized intersections where most of the collisions are transverse collisions.

On the other hand for the future studies it would be ideal to evaluate safety condition using other types of proximal indicators and also expand the current research for signalized intersections and roundabouts, implementing a more complex safety indicator like TTC. A comparison study including implementation of many kinds of safety proximal indicators will also lead researchers to a better understanding of this proactive traffic safety evaluation approach.

REFERENCES


ABSTRACT
Road accident is currently one of the main causes of death and injury in Malaysia. In addition to increasing deaths on the road every day, the remaining victims are mostly left with injuries and incapacities. The one possible way for assessment on how far people are affected by this problem can be regarded from the valuation of economical loss due to road accident. Aftermath also leaves the victim, their family and future in grief, pain and suffering.

This paper discussed the estimation the Value of Statistical Life (VOSL), using the Conjoint Analysis (CA) approach. In-person surveys using standard CA questionnaires interviewed 3000 respondents. The findings of this survey not only provide the VOSL but also demonstrated the robustness of CA method as a new valuation approach for road safety in Malaysia. A comparison between influencing factors of valuation and the estimated results between CA and CV approaches were found to be consistent. The VOSL estimated among car drivers rested at USD 0.45 million and USD 0.14 million per fatality for motorcyclists. This study also estimated the cost for injuries among car drivers at USD 0.24 million for severe injury and USD 0.11 million for slight injury. Expectedly, a lesser estimate for motorcyclists falls at USD 0.16 million and USD 0.10 million for severe injury and slight injury respectively.

1 INTRODUCTION
Road traffic accident problems had been continuously voiced by global community since decades ago. The death toll of 1.2 million people annually in road accidents around the world (WHO, 2004) proves the chronic nature of the problem. Apart from death, the rest 20 to 50 million people were left with injuries and incapacity. At current rate, road accident will expectedly raise as the world’s major disease at 9th place up to 3rd place in the next decade (Murray and Lopez, 1996).

Road accident has been reportedly claiming more lives and victim in developing region of Asia. Almost 60% of fatal accidents occurred worldwide were contributed by these countries despite only having 16% of all vehicles. It should be realized that the most vulnerable road
user in the region are motorcyclists which contributed more than half of the figure. This phenomenon is visible in Malaysia, Indonesia, Philippine, Thailand and Myanmar where motorcycles make 51% of the total vehicles. (WHO, 2004).

As mentioned, Malaysia is not exempted from the catastrophe of road accidents. Road accident is identified as a prominent cause of death and injury among Malaysian. The most updated statistics (Table 1) showed that road fatality accumulates to more than 6000 death per year or almost 20 people were killed daily. Motorcycle is the single largest group of registered vehicles, which accounts for about 67% of all registered vehicles in Malaysia. Evidently, motorcycle riders and their pillion recorded the highest number of deaths and injuries and worst of all motorcyclists consistently account for about 56% of annual recorded fatalities. It is important to note that the overall risk of death from a motorcycle accident is about 20 times greater than of cars in Malaysia (Radin Umar et al. 1995).

Table 1: General Road Accident Statistics and Fatality Index in Malaysia

<table>
<thead>
<tr>
<th>Year</th>
<th>Vehicles Registered</th>
<th>Number of Accidents</th>
<th>Death</th>
<th>Per 10,000 Vehicles</th>
<th>Per 100,000 Population</th>
<th>Per Billion VKT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>10,589,804</td>
<td>250,417</td>
<td>6,035</td>
<td>5.70</td>
<td>26.0</td>
<td>26.25</td>
</tr>
<tr>
<td>2001</td>
<td>11,302,545</td>
<td>265,175</td>
<td>5,849</td>
<td>5.17</td>
<td>25.1</td>
<td>23.93</td>
</tr>
<tr>
<td>2002</td>
<td>12,068,144</td>
<td>279,237</td>
<td>5,887</td>
<td>4.88</td>
<td>25.3</td>
<td>22.71</td>
</tr>
<tr>
<td>2003</td>
<td>12,868,934</td>
<td>298,651</td>
<td>6,282</td>
<td>4.88</td>
<td>25.1</td>
<td>22.77</td>
</tr>
<tr>
<td>2004</td>
<td>13,801,297</td>
<td>326,815</td>
<td>6,228</td>
<td>4.51</td>
<td>24.3</td>
<td>21.10</td>
</tr>
<tr>
<td>2005</td>
<td>14,816,407</td>
<td>328,268</td>
<td>6,200</td>
<td>4.18</td>
<td>23.7</td>
<td>19.58</td>
</tr>
<tr>
<td>2006</td>
<td>15,790,732</td>
<td>341,252</td>
<td>6,287</td>
<td>3.98</td>
<td>23.6</td>
<td>18.69</td>
</tr>
<tr>
<td>2007</td>
<td>16,825,150</td>
<td>363,314</td>
<td>6,282</td>
<td>3.73</td>
<td>22.8</td>
<td>17.60</td>
</tr>
<tr>
<td>2008</td>
<td>17,971,901</td>
<td>372,990</td>
<td>6,527</td>
<td>3.63</td>
<td>23.5</td>
<td>17.65</td>
</tr>
<tr>
<td>2009</td>
<td>19,020,000</td>
<td>397,330</td>
<td>6,745</td>
<td>3.55</td>
<td>23.8</td>
<td>17.28</td>
</tr>
</tbody>
</table>

1.1 The Cost of Road Accidents

Merely observing these figures alone is not sufficient to conclude the overall consequences to affected parties in the event of road accident. Not only dreadful consequences of deaths, physical injuries and property damage occurred prolong anguish and grief to families and friends of those killed and maimed pursued. Asian Development Bank (ADB) Technical Assistance (2005) highlighted the death impact of income earners at household level is almost instantly felt. Job loss and increase cost of medical treatment are frequent examples. The incapacitated victims will indefinitely need extra help and care from others to live their remaining life.

Socioeconomic impact of road accident at individual, society and national level have long been considered by developed countries in their effort to formulate better road safety. Countries like United Kingdom, Australia and Switzerland have continuously revised and update their cost valuation of road accident death and injuries.

Likewise, Malaysia needs to tackle the challenging issues of road safety. Proper remedial strategies call for appropriate funding and investment before any action plans and intervention programs can be initiated. As road safety is the sub sector of many other
pertinent government sectors in Malaysia, the need to rationalize and compete for proper financing and resources allocation is inevitable. Hence, justifying the losses and the possible future savings from accident reduction is a detrimental effort.

In line with the cost benefit analysis (CBA) principles, prospective losses due to road accidents should be in the perspective of the affected people despite the subjectivity of public perception that sometime argues safety and life valuation as unethical and insensible. Accordingly, our present ex-ante valuation studies look at how people trade-off between certain changes in their risk of death in accident with the amount of money they are willing to pay.

In Malaysia, the first known road accident costing exercise was undertaken by ESCAP in 1983 using the lost of output method. Another attempt using a wider approach of the human capital was undertaken by Maradiah (1994). He combined loss of output cost, medical treatment cost, vehicle repair cost, insurance and administrative cost and injected a certain percentage to reflect the value of pain, grief and suffering as practiced by Dawson (1967). Ex-ante costing using the willingness to pay method in Malaysia was first pioneered by Norghani and Mohd Faudzi (2003). The initial stage of VOSL study using contingent valuation method was limited to young motorcyclists. The first nationwide valuation exercise on all road users was later conducted in 2006 (Yusof et. al 2006 and Umar). The findings of this study later became the national value for each death and injury in Malaysia (Table 2).

Table 2: The Current Estimates of Road Accident Losses

<table>
<thead>
<tr>
<th>Injury Casualties</th>
<th>Base value for Losses*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>USD 370 000</td>
</tr>
<tr>
<td>Severe Injury</td>
<td>USD 37 000</td>
</tr>
<tr>
<td>Slight Injury</td>
<td>USD 3 700</td>
</tr>
</tbody>
</table>

*2008 midyear conversion rate USD1 = RM3.22

2 METHODOLOGY

2.1 Sampling Design and Distribution
The study area covers all the 13 states of Malaysia including Federal Territory Kuala Lumpur. Face to face interview was conducted by trained enumerators to ensure respondents thorough understanding before choosing their WTP appropriately. Approximately 6 months were taken to complete the whole nationwide tour to complete data collection.

The sampling design make used of stratified random sampling where the distributions of sample were stratified according to states, districts, vehicle (car & motorcycle) and ethnicity. For each state the samples were quantified based on district proportion of registered vehicle in the particular state. The initial stage of determining sampling distribution utilized the list of registered vehicles and owners from the Malaysian Road Transport Department. The sampling technique was designed in a manner to ensure the whole population in Malaysia was represented.

2.2 Questionnaire Design
This study used questionnaires as a medium to elicit out road users WTP. The questions posed are classified into 4 parts namely:
a) the introduction,
b) respondent driving details and subjective risk,
c) profiles of attributes and
d) demographic profile

Choice selection using conjoint analysis design technique was employed in the study. Thus, all the attributes are arranged to achieve orthogonal combination between attributes and level of attributes. For every injury category there are two attributes with three levels each. The 2 attributes consisted of the cost to install for a safety device to the vehicle and the risk reduction after installing the device. Full-factorial design gives 9 profiles selections which are later broken down to 3 profiles per questionnaire for each injury category. This produces 3 different sets of questionnaire with 3 profiles in each as presented in Table 3.

Table 3: Example of selection profiles in questionnaire

<table>
<thead>
<tr>
<th>PROFILE 1</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of fatality risk from 5.0 to: (in 100,000 population)</td>
<td>4</td>
<td>3</td>
<td>NO PREFERRED CHOICE</td>
</tr>
<tr>
<td>Monthly installment to be paid for a year</td>
<td>RM 16</td>
<td>RM 32</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROFILE 2</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of fatality risk from 5.0 to: (in 100,000 population)</td>
<td>2</td>
<td>3</td>
<td>NO PREFERRED CHOICE</td>
</tr>
<tr>
<td>Monthly installment to be paid for a year</td>
<td>RM 40</td>
<td>RM 21</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROFILE 3</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of fatality risk from 5.0 to: (in 100,000 population)</td>
<td>3</td>
<td>2</td>
<td>NO PREFERRED CHOICE</td>
</tr>
<tr>
<td>Monthly installment to be paid for a year</td>
<td>RM 26</td>
<td>RM 46</td>
<td></td>
</tr>
</tbody>
</table>

The strength of this study relies on respondents’ selection of cost trade off in conjunction to their risk reduction which is simulated by opting series of cost and risk reduction alternatives to respondents. The presentation of profile selection make used of stated preference approach by asking people to consider a hypothetical situation in which respondents are offered to install only one of two choices of speed controlling device to their vehicle with certain features that may help reduce their fatality risk or injury risk. The characteristics of the device are assumed equal with exception for the monthly installation cost and the efficiency of the device to reduce the base risks (fatal or injury). The pairing of 3 levels each for cost and risk reduction follows orthogonal design which was treated as the selection of attribute and alternatives. Nine profiles were produced and further divided into 3 blocks for 3 sets of questionnaire. Thus, three sets of profiles are presented in each set of questionnaire.
3 RESPONDENT PROFILE
A total of 3285 respondents were involved in the conjoint analysis study amounting to 9855 (3285 x 3) samples. The multiplications of samples are outcome of treating each profile for every injury as individual samples. Consequently, three samples are administered from a respondent. Out of 9855 samples, 855 samples were excluded inclusive of 717 samples (239 respondents) who failed to properly value their own fatal risk. The rest of 138 samples were among 46 respondents who illogically stated their monthly expenses above their monthly incomes. After the cleaning process, a total of exactly 9000 samples were examined in this survey. There were 4578 samples for cars and the remaining 4422 samples for motorcycle.

3.1 Accident History and Demographic Profile
Inspection on respondents’ accident history revealed that approximately 90% of them have witnessed road accident and more than half were involved in it. Assessment on family history revealed that half of them experienced at least one of their family members injured in road accident. Only 8% to 11% of them admitted that their family member died in road accident. Most respondents for car considered their subjective fatal risk as between 1 to 5 per 100,000 populations while majority of motorcyclists rated their subjective risk of accident fatality as between 1 to 10 deaths per 100,000 populations.

Brief examination on selected demographical profile of the samples provided the insight of age, race, gender and income distribution. For car, most of the respondents aged between 30 to 40 years with 44% while 49% of the same age group was motorcyclists. Male respondent dominates gender distribution with 55% for car and 69% for motorcyclist. Distribution of race follow the stratified sampling design with 52% and 73% of the respondents are Malay ethnic for car and motorcycle respectively. Interestingly, Chinese occupy 38% among car sample but only 16% for motorcycle. Most respondents accumulated around RM 1000 to RM 1500 per month in term of income.

4 ANALYSIS OF WILLINGNESS TO PAY BY CONJOINT ANALYSIS
Logistic regression analysis was run to cater for binary nature of the selection (i.e. higher or lower WTP) for the valuation estimates since the choices of WTP are in discrete choice presentation. Regression analysis was also utilized in the analysis to determine the variables influencing the VOSL estimates. These variables are first tested by means of correlation analysis for the possibility of multicollinearity in which the independent variables highly correlate with each other. Multicollinearity among variables was examined from their values of tolerance. The variables identified with this problem are then excluded from the analysis of influencing factors to the different WTP selection. Statistical Package for Social Science (SPSS) software package was used to accomplish the analysis.

4.1 Contributing Factors for Fatal Injury
Two different models were constructed in this valuation study i.e. car fatal injury and motorcycle fatal injury. Via correlation analysis, variables of income, race, gender, family accident history, vehicle ownership and employer for car fatal injury model are found to be significantly correlated with WTP choice and passed the multicollinearity test. Whilst factors contributing to motorcycle fatal injury model estimate are income, family history of death and injury in accident, witness accident, employer and vehicle ownership. These variables were included in logistic regression to assess the value of statistical life according to each variable.
Table 4: Variables influencing car fatal injury model from regression analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>t</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.074</td>
<td>15.295</td>
<td>0.000</td>
<td>0.914</td>
</tr>
<tr>
<td>Vehicle ownership (0=no, 1=yes)</td>
<td>-0.130</td>
<td>-4.620</td>
<td>0.000</td>
<td>0.897</td>
</tr>
<tr>
<td>Employer</td>
<td>0.033</td>
<td>2.884</td>
<td>0.004</td>
<td>0.927</td>
</tr>
<tr>
<td>Race (1=Malay, 2=Chinese, 3=Indian)</td>
<td>0.028</td>
<td>2.880</td>
<td>0.004</td>
<td>0.954</td>
</tr>
<tr>
<td>perception risk</td>
<td>-0.005</td>
<td>-2.773</td>
<td>0.006</td>
<td>0.980</td>
</tr>
<tr>
<td>Gender (1=male, 2=female)</td>
<td>-0.041</td>
<td>-2.611</td>
<td>0.009</td>
<td>0.949</td>
</tr>
<tr>
<td>family-died (0=no, 1=yes)</td>
<td>-0.058</td>
<td>-1.990</td>
<td>0.047</td>
<td>0.995</td>
</tr>
</tbody>
</table>

Table 5: Variables influencing motorcycle fatal injury model from regression analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>t</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.060</td>
<td>9.570</td>
<td>0.000</td>
<td>0.971</td>
</tr>
<tr>
<td>seen accident (0=no, 1=yes)</td>
<td>-0.117</td>
<td>-3.798</td>
<td>0.000</td>
<td>0.980</td>
</tr>
<tr>
<td>family-injured (0=no, 1=yes)</td>
<td>-0.055</td>
<td>-3.271</td>
<td>0.001</td>
<td>0.944</td>
</tr>
<tr>
<td>Employer</td>
<td>-0.034</td>
<td>-2.832</td>
<td>0.005</td>
<td>0.987</td>
</tr>
<tr>
<td>vehicle ownership (0=no, 1=yes)</td>
<td>-0.091</td>
<td>-2.371</td>
<td>0.018</td>
<td>0.974</td>
</tr>
<tr>
<td>family-died (0=no, 1=yes)</td>
<td>0.056</td>
<td>2.067</td>
<td>0.039</td>
<td>0.953</td>
</tr>
</tbody>
</table>

All of the variables analyzed in Table 4 and 5 were analyzed using dummy variables. It should be noticed that all variables are significant with p<0.05 and tol<0.8. Generally 0 refers to respondent with no experience related to accident, vehicles and driving and 1 is associated to respondent with such experiences. Dummy variable for income starts at 1 for the lowest level of income until 5 for the highest income class with more than USD 1240 monthly salary.

However, among the variables found from regression analysis, only income and vehicle ownership show mutual influence to all the models. As shown from the positive coefficient in both models, respondents with higher income are willing to pay more compared to other lower income class while respondents with vehicle possession have lower WTP as opposed to respondents not owning any vehicle.

Four variables were found exclusively influential to either car fatal injury or motorcycle fatal injury model. For car fatal injury, the negative coefficient in gender reflects that male respondents placed higher value for their safety than female. Having family members died in accident and higher perception on fatality risk also did not influence higher WTP compared to the counterpart. The race variable uses the dummy variable 1-Malay, 2-Chinese, 3-Indian and 4-other races while employer variables were dummied as 1-government, 2-private sector and 3-self employed. For race, Chinese ethnic were at the top of the ranking followed consequently by Malay and Indian ethnic. Government staff for employer variable also quoted higher price.

Motorcyclists with family being injured have lower WTP compared to the other with no family injuries whereas respondent who had witnessed any event of accident allocated more WTP compared to their opposite. Employer and family died variables showed no conclusive trend in the influence to each model as the sign in coefficients in the two models are different although both are significant.

Approximately, the estimated VOSL for Malaysia among car drivers and motorcyclists are USD 0.45 million and USD 0.14 million respectively. To allow for specific examination to every state in Malaysia, the regression is also was runned to samples according to the states.
From Table 6, the value for car ranged from USD 0.4 million to USD 0.54 million with the highest estimated in Selangor state and Federal Territory Kuala Lumpur. For motorcycle, the range is between USD 0.12 million to USD 0.17 million where the highest estimate was also in Selangor state followed by Pahang state. For both car fatal injury and motor fatal injury models, having the highest estimate in Selangor are in accordance to the fact that the state is the most developed and urbanized area compared to other states.

Table 6: The Value of Statistical Life for fatal injury (in million USD)

<table>
<thead>
<tr>
<th>STATES</th>
<th>CFI</th>
<th>MFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johor</td>
<td>0.453</td>
<td>0.140</td>
</tr>
<tr>
<td>Melaka</td>
<td>0.443</td>
<td>0.137</td>
</tr>
<tr>
<td>Negri 9</td>
<td>0.440</td>
<td>0.136</td>
</tr>
<tr>
<td>Selangor</td>
<td>0.527</td>
<td>0.163</td>
</tr>
<tr>
<td>WP Kuala Lumpur</td>
<td>0.530</td>
<td>0.164</td>
</tr>
<tr>
<td>Perak</td>
<td>0.440</td>
<td>0.136</td>
</tr>
<tr>
<td>Kedah</td>
<td>0.437</td>
<td>0.136</td>
</tr>
<tr>
<td>Pulau Pinang</td>
<td>0.434</td>
<td>0.135</td>
</tr>
<tr>
<td>Perlis</td>
<td>0.403</td>
<td>0.125</td>
</tr>
<tr>
<td>Kelantan</td>
<td>0.434</td>
<td>0.135</td>
</tr>
<tr>
<td>Terengganu</td>
<td>0.443</td>
<td>0.137</td>
</tr>
<tr>
<td>Pahang</td>
<td>0.440</td>
<td>0.136</td>
</tr>
<tr>
<td>Sarawak</td>
<td>0.431</td>
<td>0.134</td>
</tr>
<tr>
<td>Sabah</td>
<td>0.443</td>
<td>0.137</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td>0.450</td>
<td>0.139</td>
</tr>
</tbody>
</table>

*2008 midyear conversion rate USD1 = RM3.22

4.2 Contributing Factors for Non-Fatal Injury

There are 4 models for non-fatal injury analysis with 2 models for car namely car severe injury (CSV) and car slight injury (CSL) and another 2 for motorcycle namely motor severe injury (MSV) and motor slight injury (MSL). Based on linear regression analysis, 8 significant contributing variables (tol<0.8 and p<0.05) were identified i.e. income, gender, race, age, accident history, vehicle ownership, driving experience and employment background.

Tables 7, 8, 9 and 10 present the linear regression analysis performed to the 4 models of injury estimation. Similar to fatal injury analysis, all variables were substituted with dummy variable to simplify the analysis process. The sign of each coefficient of the selected variables reflects the interaction between variables and WTP. The positive sign indicates that larger value of assigned dummy variable will contribute to higher WTP.

Table 7: Contributing Variables for Car Severe Injury Model from Regression Analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>T</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.000</td>
<td>15.025</td>
<td>0.000</td>
<td>0.861</td>
</tr>
<tr>
<td>No. of years driving</td>
<td>-0.016</td>
<td>-3.024</td>
<td>0.003</td>
<td>0.832</td>
</tr>
<tr>
<td>Risk perception</td>
<td>-0.007</td>
<td>-3.789</td>
<td>0.000</td>
<td>0.985</td>
</tr>
<tr>
<td>Vehicle ownership</td>
<td>-0.079</td>
<td>-2.780</td>
<td>0.005</td>
<td>0.905</td>
</tr>
<tr>
<td>Family-died</td>
<td>-0.068</td>
<td>-2.283</td>
<td>0.023</td>
<td>0.999</td>
</tr>
<tr>
<td>Employer</td>
<td>0.025</td>
<td>2.219</td>
<td>0.027</td>
<td>0.993</td>
</tr>
</tbody>
</table>
Table 8: Contributing Variables for Car Slight Injury Model from Regression Analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>t</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.000</td>
<td>14.032</td>
<td>0.000</td>
<td>0.966</td>
</tr>
<tr>
<td>Risk perception</td>
<td>-0.008</td>
<td>-4.170</td>
<td>0.000</td>
<td>0.985</td>
</tr>
<tr>
<td>Race(1=Malay,2=Chinese,3=Indian)</td>
<td>0.031</td>
<td>3.209</td>
<td>0.001</td>
<td>0.992</td>
</tr>
<tr>
<td>Vehicle ownership (0=no, 1=yes)</td>
<td>-0.081</td>
<td>-2.995</td>
<td>0.003</td>
<td>0.953</td>
</tr>
</tbody>
</table>

Table 9: Contributing Variables for Motor Severe Injury Model from Regression Analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>t</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.000</td>
<td>6.635</td>
<td>0.000</td>
<td>0.835</td>
</tr>
<tr>
<td>No. of years held license</td>
<td>0.021</td>
<td>3.847</td>
<td>0.000</td>
<td>0.797</td>
</tr>
<tr>
<td>Seen accident (0=no, 1=yes)</td>
<td>-0.080</td>
<td>-2.640</td>
<td>0.008</td>
<td>0.991</td>
</tr>
<tr>
<td>Race(1=Malay,2=Chinese,3=Indian)</td>
<td>-0.028</td>
<td>2.495</td>
<td>0.013</td>
<td>0.997</td>
</tr>
<tr>
<td>Risk perception</td>
<td>-0.003</td>
<td>-2.215</td>
<td>0.027</td>
<td>0.993</td>
</tr>
<tr>
<td>Gender</td>
<td>0.036</td>
<td>1.967</td>
<td>0.049</td>
<td>0.914</td>
</tr>
</tbody>
</table>

Table 10: Contributing Variables for Motor Slight Injury Model from Regression Analysis

<table>
<thead>
<tr>
<th>Variables (dummy var.)</th>
<th>B</th>
<th>t</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tolerance</td>
</tr>
<tr>
<td>Income</td>
<td>0.000</td>
<td>6.441</td>
<td>0.000</td>
<td>0.863</td>
</tr>
<tr>
<td>Seen accident (0=no, 1=yes)</td>
<td>-0.099</td>
<td>-3.165</td>
<td>0.002</td>
<td>0.960</td>
</tr>
<tr>
<td>Age</td>
<td>0.003</td>
<td>3.351</td>
<td>0.001</td>
<td>0.863</td>
</tr>
<tr>
<td>Involved in accident (0=no, 1=yes)</td>
<td>-0.045</td>
<td>-2.585</td>
<td>0.010</td>
<td>0.952</td>
</tr>
<tr>
<td>Employer</td>
<td>-0.027</td>
<td>-2.165</td>
<td>0.030</td>
<td>0.981</td>
</tr>
</tbody>
</table>

All four models showed positive income contribution towards VOSL. In terms of gender difference, males are higher contributors than females but this variable is only significant in motor severe injury model. Ethnic variable is not significant for all models except in motor severe injury and car slight injury. Respondents with experience of family member/s died from accident make up for higher VOSL in car slight injury than those with no such experience. For motorcycle, the VOSL appeared to be higher for those whom had never seen accident in as can be inspected in motor severe injury but the pattern is reversed in motor slight injury models. Motorcyclists whom had witnessed accident slightly have higher VOSL compared to those with no such experience. However, the motor slight injury model shows reverse effect from respondent’s involvement in accident as the victim give lower value than otherwise.

Respondent working in government sectors significantly affected the car severe injury as they generated higher VOSL than those in private sectors. The experience in driving variable shows negative influence to car severe injury model which implies that younger driver are more willing to pay for safety. On the other hand, age is only significant to motor slight injury with the value placed higher by older respondents. Both models for car are significantly influenced with vehicle ownership in the way that people in no possession of private vehicle seems to be willing to pay more for their safety than those already own vehicles. Respondent with more license years are more willing to take higher price to reduce slight injury in motor severe injury model.

Logistic regression on dependant and independent variables gave the value of injury by states as shown in Table 11. The estimation is extended to different states in Malaysia.
because each state is distinctive in terms of the socioeconomic status, development, industrial sectors and even the road safety condition. The highest VOSL for CSV, CSL and MSV model was observed at Selangor while Sabah recorded highest value for MSL. All these highest figures were statistically significant at p<0.01.

Table 11: Value of statistical life according to injury categories and states (million USD*)

<table>
<thead>
<tr>
<th>STATES</th>
<th>Car</th>
<th>Motorcycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CSV</td>
<td>CSL</td>
</tr>
<tr>
<td>Johor</td>
<td>0.242</td>
<td>0.109</td>
</tr>
<tr>
<td>Melaka</td>
<td>0.214</td>
<td>0.031</td>
</tr>
<tr>
<td>Negri 9</td>
<td>0.229</td>
<td>0.105</td>
</tr>
<tr>
<td>Selangor</td>
<td>0.279</td>
<td>0.124</td>
</tr>
<tr>
<td>WP Kuala Lumpur</td>
<td>0.260</td>
<td>0.112</td>
</tr>
<tr>
<td>Perak</td>
<td>0.241</td>
<td>0.0992</td>
</tr>
<tr>
<td>Kedah</td>
<td>0.214</td>
<td>0.0992</td>
</tr>
<tr>
<td>Pulau Pinang</td>
<td>0.192</td>
<td>0.0961</td>
</tr>
<tr>
<td>Perlis</td>
<td>0.155</td>
<td>0.062</td>
</tr>
<tr>
<td>Kelantan</td>
<td>0.217</td>
<td>0.1023</td>
</tr>
<tr>
<td>Terengganu</td>
<td>0.205</td>
<td>0.1085</td>
</tr>
<tr>
<td>Pahang</td>
<td>0.217</td>
<td>0.115</td>
</tr>
<tr>
<td>Sarawak</td>
<td>0.223</td>
<td>0.1023</td>
</tr>
<tr>
<td>Sabah</td>
<td>0.236</td>
<td>0.1023</td>
</tr>
<tr>
<td>MALAYSIA</td>
<td><strong>0.242</strong></td>
<td><strong>0.1085</strong></td>
</tr>
</tbody>
</table>

*2008 midyear conversion rate USD1 = RM3.22

5 DISCUSSION AND COMPARISON TO OTHER STUDIES
Several influencing factors in section 4 are found to be significant in some models but not for the rest. Although the real reason remains undiscovered, the most reasonable explanation is the colinearity problem among variables. Age for instance was only significant for motorcycle slight injury model. In real life, age can be associated with level of education, driving experience, years of holding driving license and other variables. Since the analysis using linear regression excludes variables with multicollinearity problem in each model, this could be the reason why other models are not significantly influenced by age. These colinearity problems were also encountered and discussed in a valuation study conducted in Bangkok (Dissanayake, 2009).

It should also be noted also that some significant influencing variables were not according to early hypothesis and findings from other studies. Variables such as risk perception, accident history and gender are expected to influence the value similar to people with accident history (witness, self or family died or injured). Respondents with high perception on fatal or injury risks and female often quote higher values. In addition vehicle owners are thought to be more willing to pay more for their safety since they have spent money to own their car or motorcycles. Dissanayake (2009), NorGhani (2004) and Rizzi and Ortuzar (2003) also found injury experience and accident exposure to positively influence the values.

However, findings from this study discover negative influences from the three variables in almost all models of fatal and non-fatal injuries. Respondent with accident history and female seems to select lower WTP. It was further observed that respondents claimed to be more careful after having themselves or family members experiencing road accident. The case for...
female may be associated to their limited knowledge towards vehicle safety devices as compared to male respondents.

It is also our concern whether the hike up in fuel price in addition to economic downturn in Malaysia at the time this study was conducted (year 2008) may have affected the result in several ways. The frequent retrenchment of manpower in the private sector during the time of survey could also affect the lesser valuation contribution of this sector. Undoubtedly, respondents were briefed to ensure good understand on the purpose of the survey to solely value their death and injury cost due to road accidents, but they were also asked to consider their monthly spending obligations (billings, loans, rentals, school etc.) before selecting their WTP. This reminder was to avoid double counting with loss output studies thereafter. Thus, it is very likely that respondent implicitly took into account their capability of spending money during such financially demanding condition.

5.1 Contingent Valuation (CV)Mini Study
According to Mitchell and Carson (1989) the usefulness of study results to policy makers depends on demonstrating the validity of the approach. They recommended two different types of validity tests applicable to CV measures: construct validity and convergent validity. It is also important to test that the findings are reliable and stable. Follow-up surveys conducted to examine this test and almost identical results between findings will prove the result reliable (Carson et al. 1997, Whitehead and Hoban, 1999).

Prior to the nationwide study, a CV mini study was carried out covering only the Klang Valley area with a total of 300 respondents. This follow-up study is to examine the stability and reliability of the previous nationwide CV that was conducted in 2006. Since this is the second nationwide valuation study that uses a different stated preference approach, it was felt the CV mini study could serve to test the convergent validity of stated preference methods and the robustness of the outcome from conjoint analysis study.

The result from CV mini study gave the value of statistical life for fatal injury of Malaysian car drivers and motorcyclist at USD 0.40 million and USD 0.39 million respectively. The CA result mentioned earlier was USD 0.45 million and USD 0.14 million. For severe injury, CV gave the amount of USD 0.22 million and USD 0.17 million for car drivers and motorcyclists. Correspondingly, the CA estimated value for severe injury among car drivers and motorcyclist is USD 0.24 million and USD 0.16 million. For light injury the CV amount is USD 0.12 million for car drivers while USD 90 000 goes to motorcyclists. Quite similar to that the CA estimate for slight injury obtained USD 0.11 million for car drivers and USD 0.10 million for motorcyclists. The comparison of valuation results shows minimal difference between approaches which confirms the convergent validity of both CV and CA approaches of stated preference method.

The factor variables found from the mini survey are listed in Table 12. It could be seen that many more significant variables were identified by CA approach as compared to CV. However, income is largely the most influential variable since in mostly all models this variable is identified as significant. Other contributing factors like vehicle ownership, driving experience, member of family involved in accidents and the sector of employment are also found to be commonly significant in both approaches.
Table 12: Factor variables for WTP using Contingent Valuation and Conjoint Analysis

<table>
<thead>
<tr>
<th>Category</th>
<th>Car</th>
<th>Motorcycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Death</td>
<td>Death</td>
</tr>
<tr>
<td>Mini Survey (Contingent Valuation)</td>
<td>- Income</td>
<td>- Income</td>
</tr>
<tr>
<td></td>
<td>- Family injured</td>
<td>- Driving experience</td>
</tr>
<tr>
<td></td>
<td>- Age</td>
<td>- Employer</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>- Driving experience</td>
</tr>
<tr>
<td></td>
<td>Vehicle Ownership</td>
<td>- Employer</td>
</tr>
<tr>
<td></td>
<td>Severe injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Education</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Vehicle Ownership</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- No. of Years Driving</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Employer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Risk Perception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Family Died</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slight injury</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Income</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Vehicle Ownership</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Race</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Risk Perception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Family Died</td>
<td></td>
</tr>
<tr>
<td>Main Survey (Conjoint Analysis)</td>
<td>- Income</td>
<td>- Income</td>
</tr>
<tr>
<td></td>
<td>- Vehicle Ownership</td>
<td>- Driving experience</td>
</tr>
<tr>
<td></td>
<td>- Employer</td>
<td>- Employer</td>
</tr>
<tr>
<td></td>
<td>- Race</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Risk Perception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Family Died</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- seen Accident</td>
<td>- Vehicle Ownership</td>
</tr>
<tr>
<td></td>
<td>- Family Died</td>
<td>- Employer</td>
</tr>
<tr>
<td></td>
<td>- Age</td>
<td>- Risk Perception</td>
</tr>
<tr>
<td></td>
<td>Education</td>
<td>- Family Died</td>
</tr>
<tr>
<td></td>
<td>Vehicle Ownership</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. of Years Driving</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Employer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Race</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Risk Perception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Family Died</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seen Accident</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Family Injured</td>
<td></td>
</tr>
</tbody>
</table>

5.2 Percentage loss to GDP using current and proposed value
Malaysian road fatality and injury statistics from year 2008 are used to weight the value of statistical life from this study to 2008 GDP per capita. After weighting the economic loss from road accident using the values from this study to Malaysian Gross Domestic Product from 2008, it is found that death and injuries from road accident in Malaysia cost approximately 2.65% of Malaysian GDP. This percentage is undoubtedly huge compared to 0.5% to 2% loss from developed countries.

Table 13: Malaysian GDP from year 2008 and total losses from road accident death and injuries

<table>
<thead>
<tr>
<th>INJURY</th>
<th>Frequency** In 2008</th>
<th>VOSL (USD million*)</th>
<th>Loss (USD million*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEATH</td>
<td>6,527</td>
<td>0.37</td>
<td>0.40</td>
</tr>
<tr>
<td>SEVERE INJURY</td>
<td>8,866</td>
<td>0.037</td>
<td>0.20</td>
</tr>
<tr>
<td>SLIGHT INJURY</td>
<td>16,901</td>
<td>0.0037</td>
<td>0.10</td>
</tr>
<tr>
<td>TOTAL LOSS</td>
<td></td>
<td>2805.56</td>
<td>6074.10</td>
</tr>
</tbody>
</table>

*2008 midyear conversion rate USD1 = RM3.22
It is also obvious from Table 13 that the losses counted using values from this study (2008) is almost triple to the losses counted using previous (2003) value. The huge differences are mostly contributed by value of injuries which are estimated much lesser in 2003 study. Nevertheless, the former study by Faudzi et al (2003) adopted the approach of standard gamble to find the percentage of 10% from the value of life (fatal) as the estimate for injury valuation. Since this method did not include any account from the people affected i.e. road user in the valuation, the applicability is thus debatable.

6 CONCLUSION REMARK

Literature review on death and injury valuation suggested that the use of willingness to pay approach may not be appropriate in developing countries. This is associated to the nature of the instrumentation design involve in the approach which acquires certain market and pricing mechanism to value road safety. It is however argued that the action plan to improve road safety must go through the assessment of the burden in view of the affected party i.e. society. In conjunction to this, the approach of willingness to pay is adopted to value the cost of reducing road accident death and injury in Malaysia, bearing in mind the limitation that may perhaps deter the study in several ways.

The study suggests that the value of statistical life for each fatal injury involving car and motorcycle road accident in Malaysia are USD 0.45 million and USD 0.36 million respectively. Value of statistical life for each injury involving car drivers are estimated at USD 0.24 million for severe injury and USD 0.16 million for slight injury. Estimates for motorcyclist are USD 0.11 million and USD 0.10 million for severe injury and slight injury consecutively.

REFERENCES


Dawson, R.F.F., 1967. Cost of Road Accident in Great Britain. Crowthorne Road Research Laboratory


