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Road Safety on Three Continents
in Pretoria, South Africa, 20-22 September 2000
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ROAD SAFETY DEVELOPMENT IN SOUTH AFRICA

by

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1 INTRODUCTION

South Africa faces tremendous challenges to reduce the social and economic impact of road traffic accidents on its roads. The cost to the South African economy of road accidents has been estimated at approximately R13 billion per annum. Cold statistics indicate that more than 9000 people are killed per annum on South African roads and there are 36000 instances of serious injury of which 38% are pedestrians.

All stakeholders in road traffic are faced with enormous challenges to reduce the carnage on South African roads and it is clear that only a concentrated effort will lead to a reduction in accidents.

The purpose of this paper is to present conference delegates with a background to current road safety developments and initiatives in South Africa.

The paper will focus on:

- Institutional arrangements for traffic safety;
- Pertinent laws, regulations and strategy;
- Funding arrangements for traffic safety;
- Accident statistics and data collection;
- Current problems.
2 INSTITUTIONAL ARRANGEMENTS

The new political dispensation, which heralded the birth of a new South Africa, saw the creation of nine new provincial structures.

Currently, the National Department of Transport is responsible for the development of road safety policy and for the coordination, standardisation and harmonisation of transport activities.

In terms of the Constitution of the Republic of South Africa, 1996 (Act. 108/1996), the "road traffic" function has been devolved to the provinces.

The National Department of Transport and each of the nine provinces are dealing with road safety aspects such as engineering, enforcement and education and information systems. The coordination of transportation issues is conducted by the Committee of Land Transport Officials (COLTO). The Road Traffic Management Coordinating Committee (RTMCC) of COLTO is responsible for coordination of road traffic management and has a number of technical committees as indicated in Figure 1.

To facilitate provincial-local co-ordination of traffic safety it is envisaged that provincial and traffic authorities form appropriate consultative structures in all nine provinces, similar to the COLTO structure.
Figure 1: COLTO Structure with RTMCC Technical Committees

Ministerial Conference of Ministers of Transport (MINCOM)

Minister of Transport
MECs responsible for Transport

Supported by Heads of Department

Committee of Land Transport Officials (COLTO)
Civil Aviation Technical Committee
Shipping Technical Committee

Road Traffic Management Coordinating Committee
Land Transport Coordinating Committee
Rods Coordinating Committee
State Motor Transport Coordinating Committee

Road Traffic and Safety Legislation
Traffic Standards
Road Traffic Education and Communication
Overload Control
Traffic Information Systems
Training and Development
Traffic Control
Driver Training and Testing
Law Enforcement Standards, Procedures and Equipment
Roadworthiness and Vehicle Testing Stations
Incident Management

Technical Committee
Technical Committee
Technical Committee
Technical Committee
Technical Committee
Technical Committee
Technical Committee
Technical Committee
Technical Committee

Strategy 2000-2004
ARRIVE ALIVE
Credit Card Drivers Licence
Accident Report Form
AARTO
RTMC

Special projects
Special Government Commissions regarding road traffic safety have been initiated on a needs basis. These include:

a) **Road Traffic Management Corporation (RTMC) and Administrative Adjudication of Road Traffic Offences (AARTO).** The task force consisted of representatives from the National Department of Transport and provincial officials.

b) **Special Government Task Force on Improved Bus Safety**
The task force was constituted after a spate of bus accidents in the country. The task force consulted with industry role-players such as the South African Bus Operators Association (SABOA), the South African Taxi Association (SATACO) and the Road Freight Association (RFA). Detailed recommendations to prevent similar disasters in the public passenger transport and road freight industries were formulated by the task team and are being implemented.

c) **Strategy 2000 - 2004**
The National Minister of Transport initiated Strategy 2000 - 2004 to develop a sustainable short, medium and long term road safety strategy. The task team has involved the National Department of Transport, provincial officials, CSIR-Transportek and the South African Bureau of Standards (SABS).

There has also been a willingness to coordinate road safety initiatives between ministries such as the National Department of Transport, Education and Justice on a voluntary basis.
3 LAWS, REGULATIONS AND STRATEGY

The National Road Traffic Act (No. 93 of 1996) governs road traffic matters in South Africa. The Act covers rules and regulations regarding:

- Registration and licensing of motor vehicles;
- Fitness of drivers, operators and vehicles;
- Transportation of dangerous goods;
- Road traffic signs and general speed limit;
- Accident procedures and reports;
- Negligent driving and driving under the influence of alcohol and drugs;
- Registers and records.

Recently two amendments have been made to the Act, viz. No. 8 of 1998 and No. 21 of 1999. These were made to amend aspects such as: to make provision for the registration of manufacturers of number plates; to provide anew for the class of motor vehicle for which a professional driving permit is required; to provide that certain functions may be performed by the chief executive officer of the Road Traffic Management Corporation etc.

The vision of the South African transport system is encapsulated in the White Paper on National Transport Policy which was adopted on 20 August 1996.

The vision for transport is to provide safe, reliable, effective, efficient and fully integrated transport operations and infrastructure which will best meet the needs of freight and passenger customers at improving levels of service supporting Government strategies.

The strategic objective for road traffic is for the promotion and efficient implementation of integrated and coordinated road traffic management systems including all role-players in the functional areas of road traffic management. The White Paper's aim with respect to road traffic is to:

- Improve road traffic safety;
- Enhance road traffic discipline;
- Protect the expensive capital investment in the road system;
- Enhance administrative and economic order.

White Papers on transport have also been developed by most of the provinces to compliment the National White Paper.

The Road Traffic Management Strategy (RTMS) of the National Department of Transport was also launched in 1996 as an action plan to implement the traffic safety principles endorsed by the National White Paper. Three of the focus areas of the RTMS include:

- The ground work for the establishment of the Road Traffic Management Corporation (RTMC);
- The implementation of the Administrative Adjudication of Road Traffic Offences (AARTO);
• Arrive Alive road safety campaign.

3.1 Road Traffic Management Corporation

The Road Traffic Management Corporation (RTMC) concept has been developed as one of the innovative ways to overcome the dire road traffic management situation in the country. The main objectives of the proposed RTMC are to:

• Improve the quality of traffic service provision;
• Pool national and provincial road traffic powers and resources;
• Benefit the national and provincial government through partnerships with local government and the private sector;
• Introduce sound management practices;
• Secure full-cost recovery for services on the basis of the user-pays principle;
• Stimulate innovative research and development;
• Focus government on strategic planning, regulation facilitation and monitoring.

Plans are in place to establish the RTMC as an arms length statutory body enhancing operational efficiency and maximizing scarce resources. The Head Office of the RTMC will consist of a Chief Executive Officer (CEO) and managers of functional support areas and their support staff. The functional areas will be managed on a financially “ring-fenced” basis and provincial/regional offices will be established to facilitate the functioning of the RTMC. Functional areas included in the RTMC Act include:

• Vehicle registration and licensing;
• Vehicle roadworthiness and testing stations;
• Driver licensing;
• Road Safety education and communication;
• National Traffic Information System;
• Traffic law enforcement;
• Accident reporting;
• Accident investigation and reconstruction;
• Administrative Adjudication of Road Traffic Offences;
• Road safety audits.

The underlying principle in funding for the RTMC is that no authority will be financially worse off with the user paying for the full cost of services. Units such as education, communication, training and road safety audits will operate as cost centers with no direct revenue to the RTMC. Proposed funding sources for the functioning of the RTMC include:

• A percentage of transaction fees earned by the selling of services;
• Fines and penalties;
• Interest on investments;
• Monies appropriated by Parliament.
The necessary legislation for the implementation of the RTMC is currently in place and it is understood that an incremental approach will be adopted over the next one to two years.

3.2 The Administrative Adjudication of Road Traffic Offences (AARTO)

Currently the adjudication of traffic offences in South Africa is not a priority in the justice system. There has been a decrease in recent years in the successful prosecution of traffic offences and the magnitude of fines differ across the country causing frustration amongst road users and law enforcement officials.

The Administrative Adjudication of Road Traffic Offences (AARTO) Act was established in 1998 and allows for the implementation of similar systems to that operating in other parts of the world such as the United States and Europe.

The main objectives of the AARTO Act are to:

- Encourage compliance with the national and provincial laws relating to road traffic and to promote road traffic safety;
- Encourage payment of penalties imposed for infringements and to allow minor infringers to make representation;
- Establish a procedure for the effective and expeditious adjudication of infringements;
- Alleviate the burden on the courts of trying offenders for infringements;
- Penalize drivers and operators who are guilty of infringements or offences through the imposition of demerit points leading to the suspension and cancellation of driving licenses, professional driving permits or operator cards;
- Reward law-abiding behaviour by reducing demerit points imposed if infringements or offences are not committed over specified periods;
- Establish an agency to support the law enforcement and judicial authorities and to undertake the administrative adjudication process.

The implementation of AARTO is currently being undertaken on an incremental basis and forms a key component of the Strategy 2000-2004.

3.3 ARRIVE ALIVE Road Safety Program

The ARRIVE ALIVE road safety campaign was initiated by the National Department of Transport in October 1997 as a Short Term Implementation Plan (STIP) to improve road user compliance with traffic laws through increased law enforcement and communication activities and to reduce road traffic accidents by five percent of the corresponding period in the previous year.

ARRIVE ALIVE phase 1 (October 1997 to January 1998) focused on critical offences such as speeding, drunken driving and the failure to wear seat belts.
ARRIVE ALIVE phase 1 brought down the number of crashes by 7.7% (3% fewer than predicted) and fatalities by 9.3% (in real terms saving 279 lives - 12.6% better than predicted). The cost-benefit ratio was 4:1 with most of the funding coming from the Road Accident Fund.

ARRIVE ALIVE phase 2 (February 1998 to April 1998) focused on speeding and driver fatigue.

ARRIVE ALIVE phase 3 (July 1998 to April 1999) focused on speeding and drunken driving and October 1998 was designated Pedestrian Month. Pedestrian safety was particularly highlighted over this month to increase public awareness of the astonishingly high number of pedestrians who die on our roads each year (3800 or 38% of all fatalities).

ARRIVE ALIVE phase 4 (November 1999 to January 2000) targeted high-risk geographical areas and routes in the country. Traffic Law Enforcement Agencies at local and provincial level embarked on an aggressive law enforcement campaign, which included visible policing, speed timing and both static and roving roadblocks. New lower speed limit of 100km/h for buses, coaches and minibus taxis came into force. ARRIVE ALIVE 4 issued a set of key guidelines for all road users dubbed "the six commandments of ARRIVE ALIVE", viz.: Don't Drink and Drive, Don't Speed, Don't Overload, Insist on driver and vehicle fitness, Wear your Seatbelt and Promote Pedestrian Safety.

In Kwazulu-Natal intensified speed operations were conducted on the N3 corridor and other major routes leading into the province and extended throughout KZN by provincial and local authorities. Roadblocks targeting drunken driving and vehicle defects were carried out on all these routes.

In Gauteng law enforcement operations were effective and 1,413 operations were conducted across the Province. 203 roadblocks and 447 speed operations were planned and scheduled. Other operations included roadside checkpoints to check for seat belts, driver and vehicle fitness, alcohol, etc.

In the Western Cape law enforcement operations were also intensified. 750 operations - including 180 roadblocks and 440 speed operations - were undertaken on all the major routes.

The main focus of ARRIVE ALIVE phase 5 will again be on traffic law enforcement supported by awareness and communication. Measures that are being planned include:

- A corridor approach on major routes outside cities and towns;
- A significant concentration on urban areas, which contribute most of the fatal and other casualty accidents;
- The introduction of law-enforcement supportive systems;
- The elimination of hazardous locations on roads and streets;
- Obtaining the cooperation of public transport operators on special projects;
- The introduction of special pedestrian safety related projects;
- The upgrading of traffic support infrastructure.
Perhaps the most significant achievement of ARRIVE ALIVE to date has been the extent to which it has been able to get traffic police across the country working as one force on the roads.

3.2 **Strategy 2000-2004**

Recently the Minister of Transport initiated Strategy 2000-2004. Table 1 below indicates the short-term issues and action plans identified as priorities to be addressed.

<table>
<thead>
<tr>
<th>SHORT-TERM PRIORITY</th>
<th>SHORT-TERM ACTION PLAN</th>
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<tbody>
<tr>
<td>Restructuring of inspectorates</td>
<td>Bring VTS Inspectorate into NDOT and broaden the powers of inspectorates</td>
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<td></td>
<td>Expand the numbers and upgrade the capacity of the DLTC Inspectorate</td>
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<tr>
<td>Regulation of operators</td>
<td>Implement the registration of operators</td>
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<td></td>
<td>Draw up the operational procedures for safety management</td>
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<tr>
<td>Improvement of vehicle safety standards</td>
<td>Implement vehicle safety measures</td>
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<td></td>
<td>Regulate vehicle testing centers</td>
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<td></td>
<td>Upgrade vehicle testing procedures and personnel skills</td>
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<td></td>
<td>Tighten enforcement checks on VTSs</td>
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<tr>
<td>Improvement of driver fitness</td>
<td>Regulate driving schools</td>
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<td>Introduce a computerized learner driver’s test and investigate revision</td>
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<td>Clean up driving license testing centers</td>
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<td>Regulate and upgrade driving license testing centers to the KS3 driving test</td>
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<td></td>
<td>Establish a National Call Center</td>
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<td></td>
<td>Tighten up on PrDP driver fitness standards</td>
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<tr>
<td>Pedestrian safety</td>
<td>Incorporate actions in ARRIVE ALIVE business plan</td>
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<td></td>
<td>Institute a National Pedestrian Action Plan</td>
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<td>Overloading</td>
<td>Inventory of weighbridges.</td>
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<td></td>
<td>Finalisation of draft National Overload Control Strategy</td>
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<tr>
<td>Infrastructure management and upgrading</td>
<td>Implement the Road Signs Manual</td>
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</table>
3.3 The new South African Road Safety Manual

The South African Road Safety Manual, endorsed by the Committee of Land Transport Officials (COLTO), has recently been published. The manual comprises the following 7 manuals:

- Volume 1 – Principles and policies
- Volume 2 – Road safety engineering assessment of rural roads
- Volume 3 – Road safety engineering assessment of urban roads
- Volume 4 – Road safety audits
- Volume 5 – Remedial measures and evaluation
- Volume 6 – Roadside hazard management
- Volume 7 – Design for safety

Training courses and a road show to promote the new manual have been conducted and provinces such as Gauteng are busy implementing road safety audits on the provincial network.
The National Department of Transport receives an allocation from the general fiscus. Figure 2 below indicates the budget (1996-2003) without bus and rail subsidies. The total budget for the Division of Road Traffic Management within the Department is safety related.

Figure 2: NDOT Expenditure without subsidies (1996-2003)

The South African National Road Agency Ltd. (SANRAL) has used portions of its budget to conduct road safety audits and has commissioned a study to revise the geometric design standards for roads.

Provincial budgets are also provided by Central Government and provincial road and transport departments conduct their own safety programs and studies. There have been cases where provinces have made contributions to local authority budgets for the implementation of road safety measures such as the improvement of pedestrian hazardous locations.

At a local level, authorities usually provide in their budgets to provide traffic calming and other low cost measures.
Financial resources for road safety campaigns, workshops and audits are provided for at each government level to cover their own expenses in this regard. To date the Road Accident Fund has sponsored all the ARRIVE ALIVE campaigns (±R200m).

Currently the government is encouraging private public partnerships to promote traffic safety.
5 ACCIDENT STATISTICS AND DATA COLLECTION

A new accident reporting system has recently been implemented in the country. Previously, the South African Police Service (SAPS) completed the accident report form, in triplicate, for each road accident (Figure 3). The original document was kept by SAPS and copies were forwarded to the local authority and Statistics South Africa (SSA) who annually produced a comprehensive Road Traffic Collision Report.

![Figure 3: Old Accident Reporting System](image)

A number of problems existed with the system, including:

- No guarantee that all accident information reached SSA;
- Non-capturing of essential information in the national information system for use by local authorities, e.g. location of accident;
- The establishment of databases by local authorities.

The new system (Figure 4), the National Accident Register, was established by the NDOT in consultation with all of the relevant stakeholders. The SAPS completes the Officer’s Accident Report (OAR) form is to be introduced soon to be for each road accident. A Driver’s Accident Report (DAR) form is completed at the police station for “damage only” accidents.

The SAPS also completes the SAP176 Accident Register and a Delivery Note (DN) form. Relevant data of all completed OAR forms, entered in the SAP176 Accident Register is also completed in sequence on the DN form. The signed DN is kept at the police station and a copy of the DN is sent with the OAR forms to the local or provincial traffic department.
Within municipal boundaries the local authority captures the accident data in the Traffic Management System (Trafman) or equivalent system and forwards the information to the province.

Outside of the municipal areas the SAPS collects the data and forwards the information to the provinces for capturing. The province then downloads the information into the National Accident Traffic Information system (NATIS).

![Diagram of the new accident reporting system.](image)

**Figure 4: New Accident Reporting System**

In future the Annual Report on road traffic collisions will be published by NATIS.

The Automobile Association of South Africa and the AA Road Traffic Safety Foundation using statistical data made available by the CSIR-Transportek publish an Annual Traffic Safety Audit, sponsored by Mutual and Federal.
CURRENT PROBLEMS

The current situation regarding traffic safety in South Africa is disheartening. Statistics on fatalities and comparison with other countries show a sorry state regarding road traffic management in the country. While Figure 5 indicates that fatal collisions and fatalities show signs of decreasing Figure 6 demonstrates that compared to other countries fatality rates are cause for concern. The fatality rate and injury rates per 100 million vehicle kilometers are significantly higher than the total average for the other countries indicated.

Figure 5: Traffic fatalies/collisions for the period 1988-1998

Figure 6: Fatality Rate per 100m Vehicle KM
Figure 7: Vulnerability of road users (1998)

As shown in Figure 7 pedestrians and vehicle passengers constituted 38.1 and 32 percent of all road deaths, respectively, during 1998.

The main problems contributing to the sorry tale regarding the traffic safety situation in South Africa include:

- General deterioration in driving standards leading to a disregard of traffic rules;
- Lack of effective law enforcement due to inadequate resources (human and infrastructure);
- Inadequate adjudication of road traffic offences;
- Speeding;
- The propensity for driving and walking under the influence of alcohol and drugs;
- Low seatbelt wearing rate;
- Low level of road safety awareness;
- Inadequate educational programmes due to inadequate human resources;
- The current poor state of public transport (minibus taxis and buses);
- Hazardous locations;
- A high percentage of overloading on South African roads;
- Poor monitoring of road safety campaigns.
7 CONCLUSIONS

While the current state of traffic safety in South Africa is a cause for concern there are indications that there is a political will to overcome the associated problems. Short-term programs such as ARRIVE ALIVE have had some limited success in reducing the fatalities on South African roads. However, innovative initiatives such as Strategy 2000-2004 initiated and championed by the Minister of Transport and the establishment of the Road Traffic Management Corporation and implementation of AARTO are expected to yield long lasting benefits to traffic safety.

It is clear though that the road ahead will require hard work and dedication and as government is in no position to solely fund these initiatives the role of the private sector will be critical.

Conferences such as this Road Safety on Three Continents plays a crucial role in allowing South African traffic safety practitioners and stakeholders in deliberating with and learning from our international colleagues. We look forward to testing and benchmarking the solutions to traffic safety in South Africa as outlined above.
References

1. INTRODUCTION

A BAS-Project group of scientists and of practiveers elaborated during 1999 under commission of the German Federal Ministry of Transport programmatic proposals for new approaches to the improvement of road traffic safety in Germany [BREUER et al., 1999]. In this context it is important to take into account the federalistic structure of the Federal Republic of Germany with the political independence of the 16 Länder in many sensitive areas of road safety like police enforcement, school education as well as regional and local authorities investments for the road infrastructure. Federal government therefore has always to be aware, that bottom-up activities are unavoidable for a sustainable and strategic road safety work.

In the last ten years of the 20th century, 95,000 people were killed on the roads of unified Germany and 5 million people injured. Happily, despite the fact that total travel is increasing, the number of fatalities is falling steadily and in 1999 totalled 7,750, the lowest figure since official road accident statistics were initiated in 1953. Despite this, however, improvement of road safety remains an on-going and extremely important task.

The continual reduction in our quality of life caused by more than 2 million accidents each year compels us to concentrate even harder than before on improving road safety in the coming decade. Individual and communal awareness of responsibility must be heightened and a contribution demanded from everybody. The project group proposed to make each individual assume even more personal responsibility – particularly for vulnerable road users.

In the age of global communication networks, rapid technological progress, more closely integrated economic and industrial areas and grave demographic change, it is a fact that well-established values, life-styles and demands are changing more quickly than in the past. In view of tight resources and increasing demands, this
change in structures and values makes it necessary to use the synergy effects of closer collaboration between the health care sector, environmental protection and the technologically and economically supported increase in mobility in order to improve the standard of life and road safety. In an increasingly close-knit Europe, the call is becoming ever louder for accident costs to be carried to a greater extent by the party responsible for causing them in order to charge the costs fairly and to encourage safe behaviour in traffic. At the same time, the European Union emphasised in its most recent action programme that the social responsibility of state and of citizen to increase road safety were two sides of the same coin.

In order not to lose orientation and speed in the continual improvement of road safety and also to keep step with the European neighbours, the project group proposed to make heavier demands on the responsibility of the community and of each individual. Clear goals for road safety work are necessary to make this a success and allow us all to profit. For the majority of road users contributing is a matter of course – but it is only when all contribute and accept the obligation for life-long learning that the highest possible level of safety will be reached.

A constant reduction in the number of accidents and victims of these accidents, in particular fatalities and the severely injured, will serve as an indicator for the improvement of road safety. The aim is to reduce the number of both fatalities and severely-injured victims by half in the next ten years [figures 1 and 2].

The recommendations of the project group are based on the guiding principle that road accidents are not simply a fateful, unavoidable side-effect of road traffic and mobility but are in most cases result from avoidable human errors. Evaluation of accident consequences shows annual damages of approximately 70,000 million DM in Germany. Only part of the damage is carried by the parties responsible or by their vehicle insurance.

More road safety for all can only be achieved if everybody contributes. For this reason all social forces, particularly the state, must work towards everybody making his contribution, the stronger assuming responsibility for the weaker and in this way creating road safety for all. The individual measures for improving road safety are orientated towards specific goals and selected according to efficiency criteria.

The implementation of road safety measures and their effects on road safety should be observed and optimised continually. Police accident records are an important basis for objective and targeted road safety research. This basis must be maintained and improved for minor accidents.
Research carried out by the Federal Ministry of Transport, Building and Housing must include investigation of strategies, procedures and techniques for improving the safety, flow, guidance and management of traffic to better exploit existing capacities and must also look into the increased use of other modes of transport to satisfy mobility requirements and thereby reduce the load on road traffic.

2. Safety Potential

The accident development in recent years and the development forecast to 2010 for Germany show obvious areas for initiating road safety measures. With a generally favourable development of accident occurrence the main problem areas in road safety are:
- accidents involving vulnerable road users;
- accidents involving young drivers;
- accidents on rural roads.

2.1 Road Safety of Vulnerable Road Users

Vulnerable road users include children, the elderly and the handicapped but also unprotected road users such as pedestrians, bicyclists and motorcyclists. Road safety has not by any means developed as well in recent years for unprotected road users as it has for car occupants.

- safety potential for pedestrians:
  children between 6 and 9 years of age and elderly people of over 65 years of age have accidents three times as often as 35-44 year-old pedestrians; accident consequences are particularly severe in the case of elderly pedestrians. Making residential areas safe, above all through traffic-calming construction and design measures which are friendly to children and the elderly are therefore of high priority. It is also of absolute necessity to inform drivers even more intensively about age-specific behaviour patterns and the physical and psychological restrictions of children and senior citizens and to be even more insistent in urging drivers to fulfil their responsibilities regarding vulnerable road users.

- safety potential for bicyclists:
  in the coming years, 15-18 year-old bicyclists, over 55-year-old bicyclists and particularly over 65-year-old bicyclists will have the highest population-related accident risk. Road safety work must therefore provide even more detailed information for and about these target groups and propose suitable measures. On the one hand the bicyclists must recognise their responsibilities and contribute to reducing risk by riding defensively. On the other hand car drivers must take into account, and adapt themselves to, the typical behavioural patterns and deficits of bicyclists.
safety potential for motorcyclists:
today, the risk of a motorcycle user being killed in road traffic is seven times higher than that of other road users. Total motorcycle travel will increase greatly in the coming years. Road safety measures in this field (such as motorcycle safety training courses offered by the German Traffic Safety Council and his members) are therefore urgently required. As well as intensive education of the motorcyclists, such measures should also inform and motivate car drivers to a greater extent.

2.2 Road Safety of Young Drivers
Young drivers present a particular road safety problem. Approximately 22% of road fatalities are made up by 18-24 year-olds; this figure is far higher than the 8% of the population which they make up. The risk of a young driver being killed in a traffic accident is almost three times as high as a driver from the 25-34 year-old age group and almost five times as high as a driver from the 35-54 year-old age-group. A significant reduction in the number of accident victims in this age group would considerably improve the overall balance.

Forecasts lead us to expect that the group of 25-34 year-olds will gain in significance with regard to accident occurrence in the future. Measures to reduce the risk-taking and improve the road safety of young drivers should therefore if possible also bear this group in mind.

2.3 Road Safety on Rural Roads
Accidents on rural roads have particularly serious consequences: two out of three fatally injured road users die on rural roads. Also, the favourable accident development on all other categories of roads has not been equalled by any means on rural roads. If nothing is done the percentage of fatalities made up by those occurring in accidents on rural roads will continue to increase. This constitutes a particular challenge for future road safety work.

New accident analyses show that most attention should be devoted to avoiding accidents which occur:
- due to speeding;
- due to roadway runoffs;
- when overtaking.

An ecologically acceptable means of avoiding tree accidents with serious consequences would have great safety potential (30% of people killed on rural roads are the victims of tree accidents). A differentiation should therefore be made between
measures on existing avenues and requirements for the construction of new avenues.
It would exceed the scope of this paper if I listed all the measures. I have therefore restricted myself to giving an overview of the different areas in which measures are carried out.
3. Behavioural Influence

Road traffic regulations and acceptance and observance of these regulations are necessary for it to be possible to transport people and goods efficiently and safely. More than in other social areas, participation in road traffic requires of participants responsible behaviour and consideration for others. Measures aimed at behavioural influence must therefore make it clear that road traffic is not a matter of self-interest and pleasure but primarily a social task which can only bring benefits for individuals by improving safety for everybody.

To a greater extent than in the past it is a matter of making “stronger” road users, as the parties which cause most of the road accidents, the central subject of road safety work in order to provide better protection for “weaker” road users (children, pedestrians, bicyclists).

The main areas in road safety work for carrying out measures to influence behaviour are therefore in:
- road safety education, safety publicity campaigns and driver training;
- the design and enforcement of traffic law and;
- the use of positive incentives.

4. Traffic Infrastructure Design

With regard to traffic infrastructure design there are both traditional and newer measure areas with high potential for road safety.

- It is an on-going necessity to recognise local road construction and traffic management factors which are conducive to accidents and to carry out measures to make accident black-spots less dangerous.

- In road design, it should not be the case that cross-sections, horizontal and vertical alignment, equipment and maintenance are orientated exclusively to the dictates of simplicity, traffic flow and the interests of the residents but must also guarantee safety. Safety potential is therefore also seen in the area of road design. In order to detect this potential it is intended that designs for new roads and road improvement should be subjected to a so-called safety audit. The work to draw up the safety audit has already begun in a special expert group.

- Road network planning should also be used not only for regional planning aims such as traffic avoidance, traffic reduction in local authorities and good accessibility, but also for improving traffic safety.
5. **Vehicle Safety and Telematics**

Traffic safety is not conceivable without improvements in vehicle engineering. Many vehicle engineering innovations over the last 30 years were aimed at avoiding or reducing personal injury in accidents, so-called passive safety. Here considerable improvements have been achieved, both through obligatory equipment regulations (e.g. seat belts) and on a voluntary basis (e.g. airbags).

It is intended in future to support and supplement this positive development by using vehicle engineering to a greater extent than previously to avoid accidents, i.e. to improve active safety. The use of telematics in traffic can also contribute to the avoidance of accidents. The project group therefore recommended to attach increasing significance to technical innovations which aim to avoid accidents.

6. **Emergency Medical Services**

The emergency medical services constitute a public task to improve quality of life in the area of elementary care and life-saving protection against danger. This sector includes first-aid and emergency notification measures as well as the organised emergency medical services, clinical care and the post-care of accident victims and their relatives.

7. **Implementation and Funding of Sustainable Road Safety**

The implementation of safety measures and their effects on a sustainable road safety must be constantly observed and optimised. It is therefore proposed to use the Accident Prevention Report, which has been presented to parliament by the Federal Government every two years since 1973, as an instrument for controlling the implementation and success of the road safety activities in Germany the call was made for the necessary federal funds to be make available in order to guarantee planning safety, continuity and consequently the success of a long termed road safety strategy.

8. **REFERENCE**

Figure 1: Road Fatalities in Germany
- Development and Trend -

Level 1999: 7,750
Target 2010: 3,900
Trend 2010: 5,200

Target: -50%
-25%
Figure 2: Seriously Injured in Road Traffic in Germany
- Development and Trend -

Level 1999: 109,532
Trend 2010: 82,000
Target 2010: 54,000
- 36%

Target: - 50%

Level 1999: 109,532
Trend 2010: 82,000
Target 2010: 54,000
- 36%

Target: - 50%
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Experiences with Roundabouts 
in the Vestfold Region

Accidents Traffic Behaviour 
and Geometric Design

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SUMMARY

This paper has been prepared by the Public Roads Administration Vestfold. The contents of this paper discuss the results of a study concerning Roundabout safety in the Vestfold Region, Norway.

The main subjects of study are as follows:

A. Before and after studies of constructing roundabouts and their effect on traffic safety.

B. Accident risk studies for roundabouts during the period 1991 to 1995.

C. Traffic behaviour studies within selected roundabouts and the study of their geometric design.

The main results for each area of study are mentioned below:

A. Before and After Studies (22 junctions)

- The studies showed that the number of accidents resulting in injury were reduced by 34.5%.
- The average accident rates were reduced from 0.25 to 0.12
- Reduced degree of severity in the present accidents.
- There has been a tendency for bicycle accidents to increase whilst pedestrian accidents have decreased.

B. Accident Risk Studies (33 roundabouts)

- The studies showed that the average accident rates were 0.10, which is about double the normal values.
- Low degree of accidents severity
- 30% of the accidents occur at the entrance to a roundabout, and 20% occur during head to tail collisions.

C. Traffic Behaviour Studies (6 roundabouts)

- High speed at the entrance to the roundabouts
- Poor sight lines in many roundabouts.
- On average, 20% of the motorists don’t give way at the entrance to a roundabout.
- A total of 37% of the motorists do not give way to pedestrians.

INTRODUCTION
The following paper discusses the results of a study concerning the safety of roundabouts in the Vestfold Region in Norway, in the autumn of 1996.

The aims for undertaking the study were to answer the following questions:
1. Has the construction of roundabouts led to less accidents and a reduced accident risk?
2. Traffic situation evaluation and risk of accidents occurring in roundabouts?

The main areas studied were:
- The consequence of constructing 22 roundabouts and the effect on traffic safety analysed through before and after studies.
- The accident risk of 33 roundabouts.
- The assessment of traffic behaviour and geometric design of six selected roundabouts.

Almost all the roundabouts in Vestfold County have an annual average daily traffic (AADT) of between 2000 and 20,000 vehicles and are located in the city areas. The AADT is defined as all traffic entering the roundabout. Sixty five percent of all roundabouts have four junction legs and the remainder have three junction legs. Sixty five percent of the roundabouts are of medium size.

METHODOLOGY

Methodology for the Before and After Study

The chosen method for the Before and after Study is called "Before and After Study with Control Material".

The development of the control material was used to make assumptions about how the development would have been in the future without changing the geometry of the junction. The diagram below describes the process of the Before and after study.

![Diagram of the Before and After Study](image)

1. **Defining** population number, length of evaluation periods and accident statistics.
2. **Correction** of registered number of accidents in the Before Period to make them comparable to the number of accidents in the After Period. The corrections include:

a) The regression effect ($U_{CR}$)
b) General traffic changes ($C_t$)
c) General accident changes ($C_u$)
d) Unequal length of time periods ($C_p$)

The corrected number of accidents for the Before Period, $U_k$ is calculated as follows:

$$U_k = U_{CR} \cdot C_t \cdot C_u \cdot C_p$$

a) The regression effect in accident numbers, which means to correct the data for a possibly abnormal high accident number in the Before Period;

The formula for correcting the number of accidents for the regression effect is:

$$U_{CR} = \alpha \cdot U_1 + (1-\alpha) \cdot U$$

where $\alpha = U_1 / (U_1 + (U_1^2/k))$, $U$ is recorded number of accidents and $k=0.5$ for junctions on main roads in Norway. The formula for calculating the normal expected number of accidents is:

$$U_1 = AADT \times 365 \times U_{fN} \times 10^{-6}$$

where $U_{fN}$ is the normal accident rate which is calculated from the average accident rates for similar junctions.

b) General traffic changes from the Before Period to the After Period;

$$C_t = AADT_a / AADT_b$$

$AADT_a$ is the annual average daily traffic in the After Period
$AADT_b$ is the annual average daily traffic in the Before Period

c) General accident changes from the Before Period to the After Period

$$C_u = U_a / U_b$$

$U_a$ is the number of accidents in the After Period
$U_b$ is the number of accidents in the Before Period

d) Possible unequal length of time of Before and After Period.

$$C_p = Y_a / Y_b$$

$Y_a$ is the number of years in the After Period
$Y_b$ is the number of years in the Before Period

3. **Statistically testing** of the changes in accident numbers from Before and After situations. Statistically testing is used to check if the changes are statistically real or just caused by casual variation. The aim of the test is to determine if the change
in the number of likely accidents are caused by the construction of the roundabout. The test is meant to determine the level of significance, or the probability of a real change occurring.

The figure below shows how large the reduction in number of accidents must be (% of given number of accidents from Before Period) to be statistically significant for 5% level of significance (P < 0.005). This means that there is 95% probability that the reduction of number of accidents is real. The graph below is based on $\chi^2$-testing.

4. Accident rates are calculated to estimate the probability of being involved in an accident. A high number of accidents can be due to heavy traffic and the accident rate should also be calculated to describe the traffic safety in the junction.

The formula for calculating accident rates in the Before and After Periods for each junction:

$$U_f = \frac{U \cdot 10^6}{\text{AADT} \cdot 365 \cdot t}$$

The accident rate, $U_f$, is defined as the number of accidents per $10^6$ passing vehicles through the junction. $U$ is the number of accidents and $t$ is the number of years in the period.

The calculation of the average accident rate with concern on the AADT for a group of junctions:

$$U_f = \frac{\sum(U \cdot 10^6)}{\sum(\text{AADT} \cdot 365 \cdot t)}$$

The standard deviation (spread around the middle value) tells something about how much the values for each junction deviate from the average value:
Experiences with roundabouts in the Vestfold Region. Accidents, traffic behaviour and geometric design.

\[ S = \sqrt{\left( \frac{\sum (U_f - U_{fgj})^2}{n-1} \right)} \]

- **S**: is the accident rate spread inside each group of junctions
- **U_f**: is the calculated accident risk for each junction
- **U_{fgj}**: is the calculated average accident risk
- **n**: the number of observations

5. A calculation method built on average values from a large number of known junctions in Norway, is used to classify the junction as especially dangerous in the Before or After situation.

The number of accidents will most likely follow a Normal distribution as shown in the figure below.

![Normal Distribution Graph](image)

It can be shown that if the junction has a normal level of accidents compared to other junctions of the same type, the number of accidents over a period of a number of years should with 95% probability be lower than **U_{95}**:

\[ U_{95} = U_n + 1.65 \times \sqrt{U_n} \]

- **U_n**: is the expected number of accidents that can be calculated from:
  \[ U_n = 365 \times AADT \times t \times U_{fn} \times 10^6 \]
- **U_{fn}**: is normal accident rate for this type of junction.

The criteria is that if **U > U_{95}**, the junction can be classified as especially dangerous.

The formula for the **U_{95}** is empiric and should not be used for small number of accidents.

6. The results of the study are summarised and evaluated.

Please note that in this study the length of the "Before" and "After" Periods are from 1 to 5 years. The study is based on personal injury accident numbers from the police.
authorities which are registered according to the internationally accepted definition of a traffic accident.

Methodology for the Accident Risk Analysis

The junctions in the Before and After Study have various "After" periods depending on when the roundabout was built. To describe the accident risk situation, an accident risk analysis was carried out of 33 roundabouts for the period 1991 to 1995.

The accident risk analysis includes:

- The annual accidents for each of the roundabouts.
- The accident rate for each junction and the average accident rate for groups of junctions.
- Evaluation of the roundabouts to determine if any number can be described as especially dangerous.

Methodology for Traffic behaviour studies and study of geometric design

The Traffic behaviour study has the benefit of fieldwork assessment. This gives a good impression of the total traffic situation and can supply the accident studies to get a better picture of the different conditions of importance.

The roundabouts are all within the city areas and are all described as especially dangerous and therefore not representative of all roundabouts.

Behaviour recorded for the study:

- Vehicle travel speed chosen to travel into and through the roundabout.
- Vehicles giving way to other vehicles and roundabout users.

The vehicle travel speed was measured in situations with no queue, and over a distance of 30 metres before and 20 metres through the roundabout and the junction leg with the easiest curve to pass. A minimum of 40 observations was carried out for each junction leg.

A recording of vehicles giving way to pedestrians and bicyclists was carried out in junction legs with a minimum number of 100 crossings each day for each roundabout.

The recorded geometric design includes:

- The radius for the car lane straight through the roundabout
- The radius for the central island.
- The location of zebra crossing compared to the give way line
- Free sight in the roundabout
These registrations are in accordance with the manuals for geometric design and free sight given by the Public Roads Administration.

RESULTS

Before and After Study

For the total of 22 junctions the results show a reduction in the number of accidents of 34.5% as a consequence of constructing roundabouts in the period 1991 to 1995 being statistically significant. The construction of roundabouts shows a good effect for this region.

The junctions had an average accident risk of 0.25 before changing to roundabouts. After constructing roundabouts the accident risk is reduced to 0.12 being a reduction of 50%. However, the accident risk of 0.12 is more than the double of the normal value for roundabouts in Norway.

Before roundabouts were in place, 6% of the accidents in the junctions were fatal or very serious accidents. After the construction of roundabouts, no fatalities or very serious accidents have occurred.

There has been a reduction of nearly 50% of crossing drive direction accidents (statistically significant). The material also shows that there has been a reduction of pedestrian related accidents by nearly 70%. Head-to-tail accidents are reduced by over 30% and the accidents where cars crash outside the road has increased with 50%, but none of these results are statistically significant.

Accidents including non-motorised road users have led to the increase of bicycle accidents and a decrease in pedestrian accidents (not statistically significant).

Accident risk analysis

For the entire 33 roundabouts there is an average accident rate of 0.10 in the period from 1991 to 1995 being twice as high as the normal value for Norwegian roundabouts. This pattern does not change when one looks at 3 or 4 legged roundabouts in groups.

The seriousness of the accidents are low, and there have been no fatalities or very serious accidents.

The distribution of accident types shows that 30% of accidents happen at the entrance of the roundabout, 20% of accidents occur during head-to-tail collision or single accidents, and the number of accidents involving pedestrians are few.
Traffic Behaviour and Geometric Design

About 70% of the entrances to the roundabouts have an average speed of 40 km per hour or more. This indicates too little deflection in the curve through the roundabout. Three of the six checked roundabouts are not built in accordance with the manuals for geometric design concerning deflection.

Free sight conditions are not satisfied in more than 50% of the controlled junction legs with the main problem being vegetation in the central area.

On the average, 20% of vehicles do not give way to other vehicles at the entrance to the roundabout. In some of the entrances over 30% of vehicles do not give way.

The share of motorists who do not give way to pedestrians varies between the various pedestrian crossings.

For the checked junction legs, 30% of vehicles do not give way at the entrance and 40% do not give way at the exit. In situations of conflict between motorists and pedestrians a total 37% of the motorists did not give way.

ACTIONS

Two levels of actions aimed to improve traffic safety in roundabouts are given:

1. General Actions
2. Special actions for each roundabout

General Actions are as follows:

- Road safety education to be made more readily available for school students and during driving courses.
- The dissemination of information related to correct road behaviour.
- Assure that facilities are built in accordance with the manual for geometric design.
- Assure that vegetation does not hinder free sight.
- Leading lines should be marked from roundabout entrances and through the roundabout area.
- Reduce driver distraction by minimal use of advertising and traffic signposting.
- Enforce speed reduction campaigns.
- Clearly mark pedestrian crossings.
The study suggests special actions for each of the 6 roundabouts in the study of traffic behaviour and geometric design. The main solutions are as follows:

- To increase the deflection in accordance with the standards of geometric manuals by enlarging or reshaping the central island.
- To reshape the canalisation at roundabout entrances
- To line mark leading lines from the entrance and through the roundabout area
- To install speed bumps before the pedestrian crossing, forcing for reduced vehicle speed in anticipation of pedestrian movements.
- To install rumble strips prior to road junctions.
- To reduce the amount of landscaping in the centre of roundabouts with the future use of appropriate vegetation such as lawns and shrubs rather than trees.

CONCLUSION

The Before and after study shows a good effect of building roundabouts. After the construction of roundabouts there have been no fatalities or accidents of a very serious nature.

The Accident risk analysis shows that the average accident risk for roundabouts in the Vestfold Region is double the normal value for Norway. The severity of the accidents is low with no fatalities nor very serious accidents.

Traffic behaviour studies show high speed at the entrance of the roundabouts. On average, 20% of the motorists do not give way at the entrance and a total of 37% of vehicles do not give way to pedestrians. There is poor sight distance and deflection in many roundabouts.

Several actions are suggested to improve traffic safety in general and particularly for each of the 6 roundabouts included in the study of Traffic behaviour and geometric design.

FUTURE DIRECTIONS

There have been limitations in this paper due to the lack of time to clearly elaborate on specific areas. The goal of this section is to discuss topics that could assist with continuing future research and assessment.

The survey could be redone in a few years time in order to have results for the same junctions to make conclusions for a longer After Period.

For this thesis it would be interesting to look at topics such as the size of the roundabout, the speed limits and AADT.

The bicycle accidents have not been analysed in depth, due to the limitations on time. However it would be worthwhile for future analysis to combine behaviour studies and
the hospital reports of injured cyclists to get a better picture of the real situation facing bicyclists and possible remedies.

The in depth accident analysis for each roundabout is a natural consequence of the results shown in this thesis.

A standardised way of doing a Before and After Study and also an Accident Risk Study would ensure the possibility of comparing the results from different studies that result in better data for empiric values.

The behavioural study can be carried out in both dangerous and safe junctions to determine any different types of behaviour. This could also explain something about the usefulness of the methods used.
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BETTER SIGNS
FOR
BETTER ROAD SAFETY

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International Conference “Traffic Safety on Three Continents”
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Abstract

This study investigates the effectiveness of traffic signs, as described in the Vienna Convention, in sending information, warnings, and orders to drivers to create a safe driving environment. This study assumes signage affects the driver’s mind and consequently driving behaviour. Confusing signage therefore increases traffic accidents and traffic disturbances. This paper hypothesizes that:

a) Some symbols and signs are ambiguous and not easily understood.
b) Some symbols give a meaning different from design intentions.
c) Some symbols give more than one meaning.
d) Some signs give drivers the impression they are allowed to take actions that are dangerous.

The methodology used is based on field research, interviews, and surveys. Traffic signs and their usage were observed, documented, and photographed in 23 countries around the world. Drivers and other interested parties were interviewed.

The survey included questions about sixteen traffic signs which need review and reconsideration. The surveys were conducted at random to 6,000 drivers in England, France, Iran, Kuwait, Bahrain, and Ukraine, i.e., 1,000 forms to each country.

Then the survey forms were numbered and entered into the computer using SPSS statistical analysis. The results of this basic statistical analysis validate the assumptions, e.g., that perceptions and understandings of some traffic signs are very low (29.07% in the case of (A,7a) sign), and that the ambiguity of such signs can give drivers wrong and dangerous information. This confirms the need to review and change certain signs in the context of the technological, geographical, social, and psychological developments of mankind, and to standardize signage in view of increasing globalization.
Introduction

The international community lays great emphasis on traffic safety as it is considered a priority concern, due to the great number of traffic accidents.

This interest is shared by government authorities, universities, some public associations, engineering bureau, vehicle manufacturers as well as manufacturers of materials used in road construction.

All such parties are engaged in conducting studies, research, and applied experiments in order to find the best solutions for road problems and consequently improve traffic safety. Those who follow such studies and research find that these stress three aspects:

- The human element and the factors which influence his driving ability.
- Improvement of road engineering and materials used in road construction.
- Development of safety devices in vehicles.

However, the above-mentioned parties do not give due attention to the importance of traffic signs which provide communication means for transmitting messages and information from traffic departments to drivers.

Perhaps such parties presume that the currently used shapes and symbols of traffic signs are adequate designwise, and sufficient to convey accurate and clear messages to drivers, as well as advise them of required actions in order to avoid all types of risks that may exist on roads.

In this study, we doubt such presumption and attempt to prove the contrary. This attitude rests on the belief that traffic signs need reconsideration by the international community. The numerous developments in road quality, vehicle design, as well as driver psychology within the last thirty years (since the Vienna Convention was approved), were not matched by any changes in traffic signs to make them conform with such developments.

Hence, some signs have lost their significance, while others were found to give more than one meaning or convey messages conflicting with traffic safety rules and regulations.

In this paper, certain aspects of the negative impact of some traffic signs as well as proposed rectifying solutions are highlighted.

However, the main objective of this research paper does not aim at persuading the international community to adopt the proposed solutions, but rather, to convince them that the problem exists. Thereafter, we hope to persuade them to discuss the general system governing traffic signs and introduce improvements thereto.

The final step would be to lay down integrated standards for traffic signs which could serve as a worldwide reference.

In this pursuit, we should consider not only the developments that affected roads and their users during the past thirty years, since the introduction of Vienna Convention, but also the probable changes that may occur within the next three decades.
Previous Analysis of Signage Understanding

Last year at the Malmo (Sweden) conference, discussion centered around three traffic signs covered by Vienna Convention which need to be either reconsidered or cancelled altogether. The first was the “Descent”, warning sign (A, 2a). We have pointed out how most drivers misunderstood the meaning of this sign particularly in the countries where reading and writing are done from right to left. In these countries, many drivers look at the sign from right to left, thus (A, 2a) is understood to be warning of an upcoming ascent, instead of a descent. In order to solve this problem, addition of an arrow within the triangle was proposed and the merits of this suggestion were elaborated. The ratio of those who could recognize the sign without the existence of the percentage in the upper part of the triangle was (45.80%), while those who recognized it with the existence of the percentage amounted to (72.50%). However, when the arrow was added, the ratio increased to (95.00%), which is a good outcome resulting from just adding a simple arrow to the sign (table no.1).

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<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average % of the right answers in the six countries</td>
<td>45.80</td>
<td>72.50</td>
<td>95.00</td>
</tr>
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</table>

The second sign was a warning sign indicating narrowness in the lane (A, 4b, R). We have explained the fact that most traffic departments use this sign to indicate a warning against the termination of one lane of carriageway, and that majority drivers (82.74%) understand this sign to be conveying such message. Then we proved that the original meaning of the symbol namely to warn against narrowness in lanes, shoulders or the end of shoulders, but not warnings of an end of lane. A new symbol was suggested to indicate warnings against the end of carriageway lanes and in table (2) we see the proposed a new symbol (sign No.3) which was the choice of most drivers, when they were asked which sign gave them clear message of end of a lane.

The third and last sign was (A, 7a) which warns against uneven roads, but the majority of drivers (66.20%) understand it to be a warning sign against a bump due to resemblance of the shape of the sign’s symbol with a bump. A proposal was made for cancellation of the sign’s symbol from Vienna Convention together with the introduction of a
substitute symbol having quite a different appearance from a bump shape but giving the desired message indicating uneven road. In table (3) we see the sign with the symbol that was selected by most drivers (Sign no.3) as alternative for the sign’s symbol (A, 7a). This paper introduces two other signs which need to be redesigned or, replaced to improve road traffic safety.

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<tbody>
<tr>
<td>Average % of the six countries</td>
<td>5.8</td>
<td>32.5</td>
<td>47.3</td>
<td>14.3</td>
</tr>
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</table>

0.10% Gave No Opinion
The Vienna Convention lists 30 prohibitory and restrictive traffic signs: “Prohibitory and restrictive signs shall be circular... unless otherwise specified, where the signs in question are described, prohibitory or restrictive signs shall have a white or yellow background with a wide red border: the symbols and the inscription, if any, shall be black or dark blue and the oblique bars, if any, shall be red and shall slope downwards from left to right.”

This definition and the study of the design of actual signs show that prohibitory traffic signs have no uniform specification. The Convention allows a white or yellow background and black or dark blue symbols or writing, yet it does not state when each colour may be used. The Convention also allows the presence or absence of oblique bars.

In addition to these differences in design, all prohibitory signs guide drivers of different type of vehicles - and a few guide pedestrians (figure 1). Some signs carry pictorial symbols (figure 2), others are abstract (figure 3), and one sign has no symbol (figure 4).

Our main concern here is with the absence (figure 2) of the oblique bar in most of the prohibitory signs, even though the bar’s presence (figure 5) improves drivers’ recognition of the prohibitory signs’ message.

There are several reasons for associating the oblique bar with the prohibitory message. The major reason is the “no smoking” sign (figure 6), which may be seen in large numbers by everyone daily in schools, government buildings, hospitals, private companies, airports, train stations, etc., in all countries of the world. This sign’s meaning is recognized by nearly everyone, including drivers, even so it is not a traffic sign. Therefore, when drivers see a prohibitory traffic sign without the oblique bar, the sign’s meaning may seem unclear or recognition may take longer.

We conducted a survey where the sign (C, 3a) that prohibits vehicle entry was displayed in two ways. 1) without the oblique bar, as described in the convention, and 2) with the bar added. Survey participants were asked which sign prohibited vehicle entry (table 4). Almost 70% of the participants chose only the sign with the oblique bar. 450 of the 6,000 survey respondents (7.5% of the total) said both signs meant no entry for vehicles. When asked which sign delivers the stronger impact, 401 of the 450 respondents (89.11%) favoured the sign with the oblique bar.

The positive effect of the oblique bar on the sign’s message can be seen clearly, since in Britain and France, where that sign is used without the oblique bar, respondents still chose only the sign with the oblique bar by 73% and 38% respectively. If the numbers in column 4 (table 4) are added to the total number of respondents
who chose only sign 2 (column 2), these percentage will become 77% and 57% respectively. Accordingly, 76% (table 5) of the total respondents understand or prefer the sign carrying the oblique bar as the one giving the clearer message.

We believe this large percentage applies to all prohibitory signs. Most traffic regulators in the world must have reached this same conclusion because they started adding the oblique bar to prohibitory signs in their countries. This action contravened the sign specifications set in the Convention. As a result, the Convention officials decide to follow this trend—not out of conviction, but rather to keep up with the change. The oblique bar therefore was added to the prohibitory signs in the amendments made to the Convention in 1995.

However, the Convention did not make the oblique bar mandatory. On page 43 of the amendments, it allowed traffic regulators to omit the oblique bar when “appropriate”. The amendments also gave no reason for adding or omitting the oblique bar.

We see it as necessary that the Convention make the oblique bar mandatory based on our survey, which proved that most drivers prefer the oblique bar because it enhances the recognition of the prohibitory signs’ meaning. This can only improve traffic safety. All that has been said above about adding the oblique bar applies only to prohibitory signs and not restrictive signs. The latter should remain as they are in Vienna Convention. The addition of the oblique bar to prohibitory signs will divide the two group of signs, and so, help drivers to understand which signs are prohibitory and which are restrictive. The message will be delivered quickly and clearly.

<table>
<thead>
<tr>
<th>Table No. 4</th>
<th>1</th>
<th>2</th>
<th>BOTH SIGNS</th>
<th>NO. OF DRIVERS WHO PREFERRED SIGN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COUNTRY</strong></td>
<td><strong>SIGN NO. 1</strong></td>
<td><strong>SIGN NO. 2</strong></td>
<td><strong>OF DRIVERS WHO CHEOED ONLY THE SIGN WITH OBLIQUE BAR</strong></td>
<td><strong>NO. OF DRIVERS WHO PREFERRED SIGN 2</strong></td>
</tr>
<tr>
<td><strong>KUWAIT</strong></td>
<td>212</td>
<td>744</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td><strong>IRAN</strong></td>
<td>195</td>
<td>805</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>BAHRAIN</strong></td>
<td>123</td>
<td>744</td>
<td>133</td>
<td>126</td>
</tr>
<tr>
<td><strong>FRANCE</strong></td>
<td>411</td>
<td>380</td>
<td>209</td>
<td>188</td>
</tr>
<tr>
<td><strong>ENGLAND</strong></td>
<td>207</td>
<td>732</td>
<td>61</td>
<td>41</td>
</tr>
<tr>
<td><strong>UKRAINE</strong></td>
<td>160</td>
<td>765</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1308</td>
<td>4170</td>
<td>450</td>
<td>401</td>
</tr>
<tr>
<td><strong>PERCENTAGE %</strong></td>
<td>21.80</td>
<td>69.50</td>
<td>7.5</td>
<td>89.11</td>
</tr>
</tbody>
</table>

* 72 Drivers did not answer.

<table>
<thead>
<tr>
<th>Table No. 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TOTAL NO. OF DRIVERS WHO CHEOED ONLY THE SIGN WITH OBLIQUE BAR</strong></td>
</tr>
<tr>
<td>4170</td>
</tr>
<tr>
<td><strong>PERCENTAGE %</strong></td>
</tr>
</tbody>
</table>
Traffic Warning Signs That Protect Children

Protecting children against danger is the responsibility of their parents and society. Among life’s dangers to children are traffic accidents. Their parents are responsible for driving safely and obeying traffic rules to set a good example for their children and so provide them with a sound driving education. The community is responsible for enacting traffic laws that protect children in the street and in areas where they are concentrated, such as schools and playgrounds. These laws include provision of adequate lighting at street-crossings, a sufficient number of traffic signals, and signage to regulate children’s street-crossing and warn drivers of their presence.

The Vienna Convention has only one traffic sign, A-12 (figure 7), that specifically protects children. This sign warns drivers of road sections that children frequent, such as streets near school exits and playgrounds.

Having one sign is not only inadequate for regulating children’s street-crossing, but it may also increase risks because the same sign will be used near schools as well as near playgrounds and other areas. This constitutes wrong usage because the principle of any standard requires it to be clear and have only one meaning to avoid causing confusion.

The use of sign A-12 at areas other than near school will endanger children, because our survey has show that most drivers see it as a warning for school street-crossing. Of the drivers we questioned in six countries, 96.65% identified sign A-12 as a school warning sign (table 6). These drivers, at times when schools are closed (late afternoon, holidays, semester breaks, or summer vacation), may believe increasing attention and slowing down are unnecessary because no children should be around. This non-response to the warning sign used near playgrounds would expose children at playgrounds to greater danger.

Another reason why warning signs for school area and playground area should be different, is children attend school at times that differ from play times and they behave differently when going to and from school than they behave when playing games. We therefore propose creating a separate warning sign for playground areas (figure 8). This symbol is taken from the American sign W14.1 (photo 1).

Another sign needing creation is one to warn of children playing in the street. This would be used in narrow streets, particularly in cities, where no dedicated playground areas exist and where children tend to play in the streets near their homes. Also, vehicles parked on both sides of such streets obscure the sight of children playing...
or crossing the street. The symbol for this sign (figure 9), a child chasing a ball from behind a standing vehicle, is based on a Canadian sign (photo 2).

These symbols are easy to understand. Our survey asked “which of the warning signs (table 6) indicate: 1) a school, 2) children possibly at play, and 3) a playground?”.

Correct responses were high. 92.42% of those surveyed identified figure 9 as a warning that children playing in the street. 90.33% of those surveyed identified figure 8 as a warning of a playground area. These percentages prove drivers would easily understand the proposed new signs.

We also recommend creating a sign that specifies street-crossings for children near schools area (figure 10). Such a sign would resemble sign E, 11a (figure 11) in the Vienna Convention for use at pedestrian street-crossing places. This sign would be important not only for drivers, but also for children, whose safety would be enhanced by showing them where to cross the street.

<table>
<thead>
<tr>
<th>Table No. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COUNTRY</strong></td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td><strong>KUWAIT</strong></td>
</tr>
<tr>
<td><strong>IRAN</strong></td>
</tr>
<tr>
<td><strong>BAHRAIN</strong></td>
</tr>
<tr>
<td><strong>FRANCE</strong></td>
</tr>
<tr>
<td><strong>ENGLAND</strong></td>
</tr>
<tr>
<td><strong>UKRAINE</strong></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
</tr>
<tr>
<td><strong>PERCENTAGE %</strong></td>
</tr>
</tbody>
</table>
Summary

We conclude that this primary study on the efficiency of traffic signs, as a means of transferring a clear, precise and understandable information and messages from the traffic departments to the drivers, numerous remarks and facts arise which call for attention and concern of Government officials and Researchers in this field. The key facts are:

a) The symbols and signs are ambiguous in their meanings and are not easily understood, so they need to be corrected.

b) The symbols in the signs which give a different meanings apart from what they have been designed for, should be changed.

c) There are some symbols used in signs which are confusing for the drivers, so should be avoided and replaced with new ones.

Needless to say these problems in the system of traffic signs as described in Vienna Convention will have effects on driver’s understanding of the changes in road situations which affect driving behaviour and attitudes in a way that will increase the road accident rate. This study aims to reduce this effect by achieving the highest level of accuracy and transparency of messages, and to reach a uniformity of signs, which helps the drivers to respond appropriately to any type of message by establishing a level of familiarity with and prior knowledge of the meaning and use of signs in various situations.

Finally, the results of this initial study ascertain the needs for serious and rapid reconsideration and amendments to be done on Vienna convention to match the technical developments and changes in roads, and for the personal and psychological changes in users.

References


2) European Rules concerning Road Traffic signs and signals - Amendments (1) - 1995.


Novice drivers are involved in road accidents to a great extend. The objective of the EU-Project “DAN” (Description and Analysis of Post Licensing Measures for Novice Drivers) was to elaborate recommendations to solve this problem. The project, focussing on the situation in EU-countries, was partly financially supported by the Commission of the European Unions.

In a first step a recent inventory of Post Licensing Measures applied in the EU was established. In a second step a qualitative analysis of advantages and disadvantages of the different measures was elaborated based on results of evaluation studies where available, on opinions of experts participating in an international workshop and on theoretical background.

As a result of this project, carried out in 1999 and published early in the year 2000, recommendations were addressed to experts as well as to national and EU-politicians for possible future implementation of certain measures in order to save lives of novice drivers. The main results of the DAN-analysis are summarised in form of recommendations.

1. An extended supported learning period for novice drivers regardless of age should be implemented on mandatory basis at least stepwise.

   The disproportionate accident risk of novices indicates that the present driver education in the EU can still be improved. Driver education and the following phases should be harmonised and form a continuum. Post licensing measures should not rely on single components, but they should form a net of elements that supports safe beginning of driver’s career.

2. The measures of the extended supported learning period for novice drivers should be sufficiently differentiated. Novice drivers and their problems are different.

Two approaches are required:

- **General prevention for all novice drivers**: A general preventive multiphase education which also makes use of the intermediate phase including in-car training as well as psychological elements concerning personal attitudes.
• **Individual rehabilitation for violators only:** Driver improvement courses in the sense of rehabilitation focusing on personal characteristics and attitudes lead by psychologists or driving teachers. The more precisely the offence is a symptom of a socially problematic character the more rehabilitation courses shall be carried out by psychologists. At least in case of alcohol- or drug-abuse in traffic and repeated other serious traffic violations a psychologist shall be entrusted with the course. (Alcohol- or drug-abuse does not affect all novice drivers and cannot be solved with general preventive measures.)

3. **A probation period with demerit point systems and feedback of about two to five years for novice drivers as well as a central index of traffic offenders should be implemented.**

These are frame conditions to support an optimal execution of the measures of the extended supported learning period and to provide a comprehensive data basis for evaluation. Additionally, it can be assumed that this period “under observation” itself has a general preventive effect.

4. **Safe driving courses have to avoid that participants over-estimate their own skills after participation or get a misinterpretation of drivers task only as a task for mastery of vehicle manoeuvring or single emergency situations.**

Demonstration of risk should be rather emphasised than purely training. Although skidding is attractive to young people the course intention is to develop safety attitudes. Safe strategy should be emphasised: to keep out of dangerous situations rather than to cope with those.

5. **Individual feedback is an important element of any post licensing measure.**

It can also be given in group sessions with maximal 10 participants. Additional driving lessons in real traffic for evaluation of driving skills and styles are a recommendable method to realise an individual approach.

6. **A zero-Alcohol limit for novice drivers should be introduced.**

7. **Specific speed limits for novice drivers or mandatory curfews shall not be applied.**

Specific speed limits obviously bear additional risk factors. Late-night or weekend curfews shall only be promoted on a voluntary basis. At the same time subsidiary mode of transportation (e.g. “Disco Busses”) have to be organised.

8. **Quality assurance systems for post licensing measures have to be implemented.**

A standardised quality system assures a regulated conduction of post licensing measures and a transparency for the client, who is not able to judge whether a measure is appropriate or not. And it is the basis for further development of the measure. A quality assurance system must also include periodical further education and supervision of the staff.
ROAD SAFETY IN GREECE

Maria Sakki, Civil & Traffic Engineer
Head of Road Safety Equipment Division
Road Maintenance Directorate, Gen.Secretariat of Public Works
Ministry of Environment, Planning & Public Works ( E.P.& P.W )
July 2000

1. Background Data

Greece has an area of 131.957 sq.km and a population of 10.264.156 inhabitants ( last census in 1991), of which approximately 1/3 lives in the greater Athens Area ( FIG.1, FIG.2 ).

The country has a dense road network - its length covers 115.000 km - , split in three categories as follows :

- 10.000 km of National Roads ( of which approx. 500 km are Motorways )
- 30.000 km of Departmental Roads and
- 75.000 km of Municipal and Local Roads

There are about 4 million motorvehicles in Greece. On 31.12.1996 there were:
- 2.349.099 passenger cars
- 910.557 trucks
- 518.500 motorcycles over 50 c.c.
- 25.120 buses and,
- more than 1.500.000 mopeds , used widely especially in the Athens area, because of the car circulation restrictions during the working days of the week.

In 1998, a total of 24.862 road accidents occurred in Greece, in which 2.195 persons were instantly killed and 33.450 were injured ( 4.831 very seriously ). These are the usual accident rates almost every year.

As in most countries, road accidents are registered by the Statistic Service of the Traffic Police ( only where human damages- deaths and injuries- are involved ) . Road Accidents are also registered by the Statistic Service of the Insurance Companies Union which also includes material damages.

The total distance travelled in Greece has not been calculated since many years, but it is based on rough estimates. It may be noticed that this value ( vehicles x Km ), estimated in a FERSI / ETSC Report for 1998 without taking into account the number of mopeds ( which are very much involved in the correlated number of road accidents ) presented a higher accident rate for Greece. Unfortunately the absolute values of annual accidents and victims are increasing in Greece (FIG.3), however much less than the annual increase of the number of vehicles, which is among the highest in Europe (FIG.4). So, there is a constant decrease of accidents rates per 1000 motor vehicles(FIG5)

2. History: road safety situation , policies, plans and programmes

The first road safety measures after the 2nd World War were practically taken in Greece by the Highway Circulation Code published in 1959 ( which became a law in 1962), as well as by the establishment of the new traffic signalling and signing system in Athens .

After the Vienna (1968) and Geneva ( 1971&1973) Conventions for the Road Signalization and Circulation signed also by Greece, the above mentioned Code was replaced by a new law in 1977.
The Code was the base for the road safety in Greece for many years, but road accidents continued to increase, especially during the days with traffic peaks (holidays, long week-ends etc.). As in most countries, the authorities blamed road users as responsible for the 90% of the accidents, due mainly to their high speeding, wrong behaviour, abstraction etc. and the recommended remedy has almost always been the strict «punishment» of the driver! Still it is considered that the main responsibility for the road accidents belongs to the drivers.

The first scientific analysis of the road accident problem was elaborated by the Ministry of E.P. & P.W. in the early 80’s. The product of this analysis was the determination of black spots on the national road network and the proposed short term interventions, realised in the frame of the Road Maintenance Programmes (1985). In general, there were no special safety budgets.

In 1986, the Year of Road Safety, Greece participated actively in the campaign initiated by the European Commission.

The results of the above mentioned actions became evident in the relevant diagrams, showing the decrease of road accidents in the years that followed (1987, 1988).

Unfortunately, this systematic policy for the national road infrastructure initiated by the Ministry of E.P. & P.W did not find imitators among the partners and Authorities responsible for the rest of the road networks (regional and local ones), as well as the other accidents’ factors (drivers, pedestrians, vehicles, enforcement procedures etc.).

Therefore, no systematic road safety policy was carried out in the late 80s and in the early 90s. The main co-ordination among the authorities and “third parties” competent for the road safety responsibility in Greece, was achieved during the elaboration of the new code of 1992 and during the interministerial meetings aiming at the measures to be taken for the prevention of road accidents during holidays, when traffic flows are very high.

3. Today: characteristics of road safety policy in the mid 90s

The main objective of the Ministry of Environment, Planning & Public Works (E.P & P.W.) for reducing the road accidents in Greece is the transformation of the important road axes with high traffic flows into Motorways (approx. 3000 km of highways, FIG.6). The Annual Maintenance Programmes of the Ministry (about 1 million EUROs) include also the low cost interventions on the national road network. Only in some cases there are special safety budgets available. The regional bodies are responsible for the rest of the road network.

Besides the above mentioned objectives, there has been a number of other actions, less costly but more dedicated to the Road Safety. In 1994, with the initiative of the Ministry of E.P & P.W., THE WHITE BOOK on Road Safety was published by an appropriate committee of experts. At the same time the Technical Chamber of Greece (T.E.E.) financed a similar Study on Road Safety and the 1st Congress of Road Safety was held in Greece, co-organised by the Aristotelian University of Thessaloniki (A. U. TH) and the Ministry of E.P. & P.W.

These actions were the preliminary steps of another more important and mature action, which was the establishment of a parliamentary committee, reinforced with experts of the Administration, Universities and non profit “third parties”.

The product of the above mentioned committee’s work was the report in depth on Road Safety with conclusions and concrete proposals, which were adopted by the Greek Parliament, for the first time in the road safety’s history.

The 2nd Road Safety Congress was held in Greece last year and a new Traffic Code has just been published, replacing the old one of 1992.
During the last 5 years of the struggle against road accidents increase, the following were achieved:

- Better co-ordination among the authorities and bodies involved and responsible for the road safety factors.
- The Ministries of Transport, of E.P.& P.W., of Public Order, of Interior, of Justice, The Regional and Local Authorities, Mass Media, Universities and Researchers, Technical Associations as well as The Automobile, Insurance and Medical Sectors.
- The foundation by law of a National Interministerial Council for Road Safety
- The establishment of a new Road Safety Bureau within the Ministry E.P.& P.W., having as objectives the elaboration of the road accident data and the determination of the black spots in order to ensure the continuous improvement of the national roads (There remains a lack of similar actions on the other levels, responsible for the departmental and municipal roads).
- The development of the Police Statistics and the connection with the European Data Base C.A.R.E.
- Better awareness of the citizens on the road accidents’ problem
- Better information by the Mass Media.
- Introduction of the road safety items in education of children and young people
- Greater interest by the Authorities (central, regional and local ones), especially by the Government and the Parliament, towards an effective road safety policy.
- Stronger enforcement and control carried out by the Traffic Police
- Better publicity and campaigns on Road Safety by the parties involved
- Major improvement of the national road infrastructure

4. Future: further development

The basic steps have been taken and the foundations have been set for a more effective policy towards decreasing of the road accidents in Greece. However, the problem is still very much present and there is a strong need for more cost effective measures, taken not only by the central authorities but also by all interested parties on every level. The persons and experts involved should be as many as possible, dedicated to this aim and engaged voluntarily in the road safety operations. The creation of Working Groups of private initiative interested in road safety, gives many hopes that the minimization—if not the elimination—of the road accidents, will be achieved finally in the near future.

Greek Publications consulted:

- Studies on road accident analysis and improvement of road safety (1985)
- Highway Codes of Circulation (1977, 1992, 1999), Greece
- Parliamentary Committee Report and Proposals (1996)
- The National Statistic Service publications, Greece
- The National Technical University of Athens (1999) and the Hellenic Institute of Transportation Engineers (1998) Researches on Road Safety.
- The Insurance Companies Publication on Road Accident Data (1998)

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e-mail: jamasak@otenet.gr

Figure 4: Evolution of the Motor Vehicles in Greece

- Number of Vehicles in the Greater Athens Area
- Total Number of Vehicles in Greece
FIG. 6
FIG. 1 GREECE = ELLAS: An European Union Country in South Eastern Europe
INTRODUCTION

The aim of this paper is to compare and analyse the road safety and traffic behaviour of road users in the Baltic and Nordic countries (excluding Iceland)- two neighbouring regions between 54 and 70 northern latitude and 5 and 30 eastern longitude. After re-establishing their independence in 1990-91 the differences between the Baltic and Nordic countries have started to decrease.

1. BASIC DATA

The main road safety and economic indicators of selected countries are based on official statistics /1…8/ and show how the data differs from each other in the big scale, but much more inside the Baltic countries (table 1, figure 1). The Nordic countries together with the United Kingdom have the lowest risk of road deaths in the world.

Table 1
Main road safety and economic indicators in selected countries, 1998

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Lithuania</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population, 1000</td>
<td>1441</td>
<td>2458</td>
<td>3704</td>
<td>5147</td>
<td>8854</td>
<td>4431</td>
<td>5295</td>
</tr>
<tr>
<td>Motor vehicles, 1000</td>
<td>538</td>
<td>650</td>
<td>1100</td>
<td>2329</td>
<td>4145</td>
<td>2213</td>
<td>2179</td>
</tr>
<tr>
<td>Cars per 1000 pop.</td>
<td>312</td>
<td>196</td>
<td>265</td>
<td>393</td>
<td>428</td>
<td>403</td>
<td>343</td>
</tr>
<tr>
<td>M.veh. performance, mill.km</td>
<td>6282</td>
<td>7230</td>
<td>13320</td>
<td>44830</td>
<td>66400</td>
<td>30920</td>
<td>44030</td>
</tr>
<tr>
<td>Fatalities (F)</td>
<td>284</td>
<td>677*</td>
<td>829</td>
<td>400</td>
<td>531</td>
<td>352</td>
<td>499</td>
</tr>
<tr>
<td>Injuries (I)</td>
<td>1990</td>
<td>5364</td>
<td>7667</td>
<td>9097</td>
<td>21356</td>
<td>12472</td>
<td>9175</td>
</tr>
<tr>
<td>F per 100 injuries</td>
<td>14.3</td>
<td>12.5</td>
<td>10.8</td>
<td>4.4</td>
<td>2.5</td>
<td>2.8</td>
<td>5.4</td>
</tr>
<tr>
<td>F per 1 million of pop.</td>
<td>1.97</td>
<td>2.75</td>
<td>2.24</td>
<td>0.78</td>
<td>0.60</td>
<td>0.79</td>
<td>0.94</td>
</tr>
<tr>
<td>F per 10 000 veh.</td>
<td>5.28</td>
<td>10.42</td>
<td>7.47</td>
<td>1.72</td>
<td>1.28</td>
<td>1.14</td>
<td>1.13</td>
</tr>
<tr>
<td>F per 100 mill.veh.km</td>
<td>4.52</td>
<td>9.36</td>
<td>6.22</td>
<td>0.89</td>
<td>0.80</td>
<td>1.14</td>
<td>1.13</td>
</tr>
<tr>
<td>I per 100 mill.veh.km</td>
<td>31.7</td>
<td>74.9</td>
<td>57.6</td>
<td>20.3</td>
<td>32.2</td>
<td>40.3</td>
<td>20.8</td>
</tr>
<tr>
<td>GDP, USD, 1997</td>
<td>7700</td>
<td>5700</td>
<td>6400</td>
<td>20800</td>
<td>20700</td>
<td>26300</td>
<td>24200</td>
</tr>
<tr>
<td>GID, 1997, ranking in the world</td>
<td>46</td>
<td>63</td>
<td>52</td>
<td>11</td>
<td>6</td>
<td>2</td>
<td>15</td>
</tr>
</tbody>
</table>

Remark: * 7 days data converted to 30 days data by k=1.08

United Nations’ Human Development Report, 2000 /8/ indicates GDP and GID (Global Index of Development), which takes into consideration average life time, educational level and income per capita. The position number of the country is shown in the last row of table 1.

Figure 1. Rate of fatalities (F) in road accidents
There are considerable differences in road safety situation in the Baltic and Nordic countries, but members of both groups have a progress. During the period of 1988-1998 the number of fatalities per 10 000 motor vehicles have been reduced from 9.6 to 5.3 in Estonia, 19.5 to 10.4 in Latvia, 15.3 to 7.5 in Lithuania, 3.2 to 1.7 in Finland, 2.1 to 1.3 in Sweden, 2.0 to 1.6 in Norway and 3.8 to 2.1 in Denmark. The figure 2 shows the development of this ratio in selected countries during the period of 1973-1998.

Figure 2. Number of fatalities per 10,000 motor vehicles.

The comparison shows, that the today’s safety level of the Baltic countries is comparable to that in the Nordic countries in 1970-1975.

Although the definition of injury varies from country to country, the trend of injury data could be observed for each country separately. Accident data of the Nordic countries indicate the growth of the number of injured road users during last 18 years, except Denmark, in spite of the number of fatalities and severe injuries have decreased significantly at this time. The progress that the Baltic countries have made in the last decade is not sufficient, thus the experience of the Nordic countries could be set as an example for the Baltic countries.

Continuous improvement of road safety indicators in the Nordic countries is a result of regular and well-planned activities, based on long-term and flexible 3-years programmes approved by parliaments of each country.

The deeper research and analysis between the selected countries is given in following.

2. COMPARISON BETWEEN THE BALTIC AND NORDIC COUNTRIES

2.1. Accident location

All the selected countries are highly urbanised. There are 69% of Estonian and Latvian, 68% of Lithuanian 76% of Finnish, 84% of Swedish, 74% of Norwegian and 85% of Danish population is living in urban settlements. When dividing the fatality data by the location we get data as follows in table 2.

Table 2
Fatalities location, 1998

<table>
<thead>
<tr>
<th>Location</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Lithuania</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban areas</td>
<td>80</td>
<td>296</td>
<td>361</td>
<td>106</td>
<td>168</td>
<td>71</td>
<td>174</td>
</tr>
<tr>
<td>Rural roads</td>
<td>204</td>
<td>381</td>
<td>468</td>
<td>294</td>
<td>363</td>
<td>281</td>
<td>325</td>
</tr>
<tr>
<td>Total</td>
<td>284</td>
<td>677</td>
<td>829</td>
<td>400</td>
<td>531</td>
<td>352</td>
<td>499</td>
</tr>
<tr>
<td>% of urban areas</td>
<td>28.2</td>
<td>43.7</td>
<td>43.5</td>
<td>26.5</td>
<td>31.6</td>
<td>20.2</td>
<td>34.9</td>
</tr>
<tr>
<td>% of pedestrians, killed in urban areas</td>
<td>12.0</td>
<td>22.0</td>
<td>23.6</td>
<td>9.3</td>
<td>8.1</td>
<td>5.1</td>
<td>11.2</td>
</tr>
</tbody>
</table>
Fatalities location share between Estonia and the Nordic countries, as well as between Latvia and Lithuania is relatively similar. The share of urban fatalities in last two countries is remarkably higher, partly because of speed limit of 60 kph, when other countries have urban speed limit of 50 kph. Also Latvia introduced the 50 kph urban limit at the end of 1998. The share of urban fatalities was in 1998 high in other countries with speed limit of 60 kph: Belarus- 42.7, Poland- 48.6, Russia- 51.1, Ukraine-61.5, Kazakhstan- 73.7% /9/.

Reducing the speed limit from 60 to 50 kph can reduce the number of accidents and especially their severity. The interval of speeds 40…70 kph (at 60 kph limit) which is a hitting speed in most of pedestrian accidents, gives an average probability of fatality accidents as 56%, when the interval of 30…60 kph (at speed limit of 50 kph) is as 40%, data based on Ashton curve.

The share of pedestrian deaths in urban areas from all fatalities was 26% in Belarus, 28% in Russia, 29.3% in Ukraine and 50.5% in Kazakhstan, as the same percentage in the Nordic countries lies at 5…11% (data of 1998).

2.2. Fatalities by road user groups

Figure 3 shows the share of fatalities (in per cents) by different road user groups. The share of pedestrians and car passengers in the Baltic countries is bigger than in the Nordic countries, where the share of drivers, cyclists and moped drivers is bigger.

![Fatalities by road user groups](image)

Remark: * In Denmark- drivers+passengers.

Figure 3. Fatalities by road user groups, 1998.

The pedestrian behaviour in the Baltic countries is very risky both on urban and rural roads. Drunken walking, red light infringement, walking on right hand shoulder, insufficient use of reflectors, etc. risky behaviour is very common.

The maximum difference between the safest and unsafest countries by road user groups are: pedestrians 11.8 times, car passengers- 8.5 times, car drivers- 2.8 times, motor cyclists- 5.8 times and cyclists and moped drivers- 2.4 times.
Figure 4. Number of fatalities per 100,000 of population by road user groups

When the bicycle ownership in Finland is found to be 625 per 1000 inhabitants, and even more in Denmark, thus in The Baltic countries this level is approximately 100, but there is a tendency of increase.

The frequent use of bicycles and its high safety risk causes a need for the light traffic network reconstruction and development. For comparison- there are 3900 km of cycle routes in Finland (1998).

The pedestrian safety is and remains to be one of the main problems of road safety in the Baltic countries.

2.3. Fatalities by age groups and gender.

Figure 5 shows the number of fatalities per 100 000 inhabitants by age groups. In the Nordic countries, the population related risk of fatal accidents is particularly high for age groups of 18…20 and over 65. In the Baltic states the high risk population groups are drivers of the age 18…54 In all countries the most risky are young people of age 18…20 with relatively low car ownership level.

Figure 5. Fatalities by age groups

The young novice drivers with passengers meet particularly high risk at weekend nights, after visiting disco-bars or pubs.
Male involvement in fatalities and injuries is higher than females, partially because of bigger exposure (kilometres driven).

Table 3
Killed and injured males, 1998

<table>
<thead>
<tr>
<th>Casualty</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Killed, %</td>
<td>78.2</td>
<td>76.1</td>
<td>72.3</td>
<td>77.2</td>
<td>72.4</td>
</tr>
<tr>
<td>Injured, %</td>
<td>65.4</td>
<td>66.6</td>
<td>…</td>
<td>58.5</td>
<td>…</td>
</tr>
</tbody>
</table>

2.4. Fatalities by collision types

There are fatality data of collision types share in table 4.

Table 4
Share of fatalities by collision types, %

<table>
<thead>
<tr>
<th>Collision types</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single vehicle accident</td>
<td>35.2</td>
<td>23.5</td>
<td>21.8</td>
<td>30.7</td>
<td>30.1</td>
</tr>
<tr>
<td>Accident between motor vehicles</td>
<td>24.7</td>
<td>28.5</td>
<td>50.3</td>
<td>36.7</td>
<td>48.3 *</td>
</tr>
<tr>
<td>Accident with mopeds or cycles</td>
<td>7.0</td>
<td>6.4</td>
<td>4.5</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Collision with obstacle</td>
<td>2.5</td>
<td>7.4</td>
<td>4.2</td>
<td>6.6</td>
<td>4.3</td>
</tr>
<tr>
<td>Pedestrian accident</td>
<td>28.2</td>
<td>33.8</td>
<td>14.0</td>
<td>12.6</td>
<td>14.2</td>
</tr>
<tr>
<td>Other types</td>
<td>2.4</td>
<td>0.4</td>
<td>5.2</td>
<td>3.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The most common accident type in the Nordic countries is collision between the motor vehicles, covering 37…50% of total. In Estonia and Latvia, the share of pedestrian accidents is more than two times bigger than in the Nordic countries.

Figure 6 shows the number of fatalities by collision types per 100 millions vehicle km.

![Fatalities by collision types](image)

Figure 6. Fatalities by collision types.

Estonian and Latvian numbers are extremely higher than in Nordic countries, especially by pedestrian and single vehicle accidents.
3. ROAD USER BEHAVIOUR

3.1. Drinking and driving.

Drinking and driving is legally prohibited in Estonia, where the traffic code states the 0-level. In Sweden 0.2, Lithuania 0.4, in Latvia, Norway, Denmark and Finland the 0.5 pro mill level has been introduced. In spite of this, drinking and driving is still remaining to be a very serious problem in all countries, playing a part in 24% of fatal accidents in Estonia, 25% in Finland and Denmark, 33% in Latvia, 17% in Lithuania and 7% in Sweden.

In the Baltic countries alcohol beverages are available during 24 hours during the whole week. In Finland, ALKO shops are open from 9 a.m. until 8 p.m. on working days, between 9 a.m. and 4 p.m. on Saturdays, when closed on Sundays. The alcoholic beverages sale limitations are introduced in other Nordic countries too.

The most effective countermeasures against drinking and driving are total enforcement and drivers’ testing with RBT in parallel with forced punishment.

The annual number of RBT in Sweden is about 2 millions, to achieve this level there must be done some 900 tests daily in Estonia. Also the legislation support should be developed further, e.g. the error pointing system has been planned to introduce in Estonia in the next years.

The RBT started in Finland in 1979 and in Estonia in 1999. There are some results of these tests of blood alcohol concentration (BAC) level /10/.

Table 5
Share of drunken drivers by RBT, %

<table>
<thead>
<tr>
<th>Country</th>
<th>Period</th>
<th>No of tests</th>
<th>Level of alcohol, BAC per mill</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.01-0.5</td>
</tr>
<tr>
<td>Finland</td>
<td>Jan-Dec, 1998</td>
<td>82783</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>June 1999</td>
<td>35650</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>July-Dec, 1999</td>
<td>48130</td>
<td>...</td>
</tr>
<tr>
<td>Estonia</td>
<td>Jan-June, 2000</td>
<td>42152</td>
<td>...</td>
</tr>
</tbody>
</table>

Drinking and driving in Estonia is considerably higher than in Finland. In result of the 1999 campaign, including massive RBT enforcement, forced punishment, public campaigns (incl.TV clips) and published list of drunken drivers, the share of drinking and driving (drivers with BAC over 0.5) is decreased almost twice.

In Sweden, the number of trips driven by drivers under influence of alcohol is estimated to be 3-4 million trips annually. In average, 0.1-0.2% of drivers are estimated to drive under the influence of alcohol or drugs, but at weekend this ratio could reach 0.5% or even more /11/. In an international perspective the Swedish numbers are quite low. There are several punishments awarded on drunken driving. The driver could be sentenced to drunken driving when during or after drive is found to have 0.2 per mill BAC and aggravated drunken driving, when the BAC is 1.0 per mill or more. The drunken driving will mostly get a summary fine of 40 x one thousand of the suspects yearly income. The summary fine will increase progressively as the BAC is coming closer to aggravated drunken driving.

The maximum punishment of aggravated driving is at maximum of two years imprisonment. At a BAC level of 0.5 per mill the revocation of a driving license is compulsory. The restriction time of revocation is connected to the level of BAC and can be 4…12 months. A person sentenced to aggravated drunken driving must undergo a number of medical and psychological testing procedures during 18 months. If a driver repeatedly is driving under influence of alcohol the court can confiscate his or her vehicle.
In Finland a driver with BAC of 0.5 per mill can be punished with 30 daily fines or up to 6 months of imprisonment. By aggravated drunken driving with the BAC of 1.2 per mill or more, the punishment can be 60 daily fines or up to two years of imprisonment. Daily fine is considered to be 1/60 of average monthly net income minus 1500 Finnish Marks.

In Estonia, the fine of drinking and driving is 50…150 minimum daily allowances (today 46 EEK or approximately 3 USD), revocation of drivers licence for 1…2 years or imprisonment of 15 days. Doubled infringement could be punished by fine of 100…250 daily allowances, revocation of the licence up to 3 years or imprisonment for 30 days.

3.2. Speeding

There are introduced different speed limits in selected countries.

Table 7

<table>
<thead>
<tr>
<th>Type of road</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Lithuania</th>
<th>Finland</th>
<th>Sweden</th>
<th>Norway</th>
<th>Denmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streets, regular</td>
<td>50</td>
<td>50 1)</td>
<td>60</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Highways, regular</td>
<td>90 2)</td>
<td>90</td>
<td>70/90 3)</td>
<td>80</td>
<td>70/90 4)</td>
<td>80 5)</td>
<td>70/80</td>
</tr>
<tr>
<td>Motorways: Cars</td>
<td>-</td>
<td>110</td>
<td>110/130 6)</td>
<td>120 7)</td>
<td>110</td>
<td>90</td>
<td>110</td>
</tr>
<tr>
<td>Buses</td>
<td>-</td>
<td>90</td>
<td>110</td>
<td>80/100 8)</td>
<td>90</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Vans &lt;3.5 t</td>
<td>-</td>
<td>90</td>
<td>110</td>
<td>80</td>
<td>-</td>
<td>-</td>
<td>70</td>
</tr>
<tr>
<td>Trucks &gt;3.5 t</td>
<td>-</td>
<td>80</td>
<td>90</td>
<td>80</td>
<td>90</td>
<td>80</td>
<td>70</td>
</tr>
</tbody>
</table>

Remarks: 1) since 1998; 2) cars on selected roads in summer period: 100 or 110; 3) trucks 70; 4) on selected roads 90 for cars and buses; 5) cars and buses: 80; 6) on two motorways: 130; 7)on winter: 100; 8) for special buses: 100.

Because of the higher speed limit on highways and motorways it will be unable for the Baltic countries to reach the road safety level common in the Nordic countries. Generally the Baltic highways are wider, often unmarked and also the quality of pavement as well as the winter maintenance is not comparable with the Nordic roads.

In result of the road users study in Estonia, the majority of road users will accept higher speed limits for summer period and decreased speed limits at the winter period /12/.

In Finland, on roads with the speed limit of 60 kph, the driver who speeds up to 20 kph must pay 500…700 FIM and on roads with speed limit over 60 kph- 400…600 FIM. When speeding is more than 20 kph the punishment can be 30 daily fines or up to 2 years of imprisonment.

In Estonia, the punishment of speeding is as follows:
- up to 20 kph: 1-5 minimum daily allowances (MDA);
- 20-40 kph: 10…60 MDA or revocation of drivers licence for 1…3 months;
- over 40 kph: 60…150 MDA or revocation of licence for 3…6 months.

3.3. Use of seat belts

Seat belt wearing became compulsory for drivers and front seat passengers in cars in 1973 in Estonia and 1975 in Finland, for rear seat passengers 1987 in Finland and 1992 in Estonia.

The Finnish National Public Health Institute has monitored health behaviour in Finland since 1978 using annual postal surveys. Estonia connected to this survey in 1990, Lithuania in 1994 and Latvia in 1998. The primary purpose of the follow-up is to obtain information on health behaviour, use of health services and involves a number of questions about traffic behaviour. For these surveys a random sample population of each country of age group of 15…64 was selected from the National Population Register /13,14,15, 16/.

The results of seat belt usage in 1998 are presented in table 7.
Table 7.
Use of seat belt in selected countries, %

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Estonia</th>
<th>Latvia</th>
<th>Lithuania</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the front seat:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearly always</td>
<td>78.1</td>
<td>67.4</td>
<td>75.5</td>
<td>94.5</td>
</tr>
<tr>
<td>Sometimes</td>
<td>11.1</td>
<td>20.0</td>
<td>14.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Never</td>
<td>1.5</td>
<td>3.0</td>
<td>2.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Never use a private car</td>
<td>9.4</td>
<td>9.6</td>
<td>7.1</td>
<td>0.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>In the rear seat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nearly always</td>
<td>11.2</td>
<td>5.1</td>
<td>1.1</td>
<td>75.1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>22.8</td>
<td>13.6</td>
<td>3.8</td>
<td>16.6</td>
</tr>
<tr>
<td>Never</td>
<td>32.8</td>
<td>52.6</td>
<td>60.7</td>
<td>5.2</td>
</tr>
<tr>
<td>No seat belt on rear seat</td>
<td>20.9</td>
<td>18.2</td>
<td>26.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Never travels on rear seat</td>
<td>12.3</td>
<td>10.6</td>
<td>8.4</td>
<td>2.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

From the table 7 and other detailed results of monitoring we can make the following conclusions:

- There are little difference in use of seat belts in the front seat and a huge difference on a rear seat between the Baltic countries and Finland;
- Females use the seat belt more frequently than male drivers;
- The use of seat belts is the lowest for male age groups of 16-24;
- The results of a postal survey are better in general than that of a road survey (in Estonia (1999)- in front seat: 65% and 11% on rear seat.

Liikenneturva /10/ had found that in Finland (1998) the share of seat belt users was on rural roads 93% and 84% on streets (in front seat), and 72% on the rear seat. The use of seat belts in Sweden and Norway is approximately on the same level as in Finland /17/.

Accident registration data shows that the use of seat belts in Estonia in accident situation reaches 48% for drivers, 44% for front seat passengers and 19% for rear seat passengers. The use of seat belts can reduce the fatality risk about 40%. If the seat belts usage will reach the level of some 90% usage (as in the Nordic countries) the number of fatalities could be reduced annually by 0.4*(90-40%)=20%. In spring 2000 the campaign of seat belt usage was made in Estonia, in TV and exhibitions.

Many drivers have taken off the front seat head restraints or these are in too low position. In result, there are lot of fatalities and injuries, resulting by chaining the victims into wheelchairs for the rest of their life.

3.4. Reflectors usage

The mandatory use of pedestrian reflectors on rural roads has been introduced in Finland in 1960, and in Estonia in 1995 (it was recommended since 1987). Comparison of data in selected countries is presented in table 8 /13, 15, 16/.

Table 8
Use of reflectors, while moving in darkness in areas without lightning, % (1998)

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Estonia</th>
<th>Lithuania</th>
<th>Finland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearly always</td>
<td>19</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Sometimes</td>
<td>19</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>Never</td>
<td>62</td>
<td>90</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Remark: answers “never walk on unlighted streets” has been excluded from table.

The most active group in reflectors use are women age 55…64 and most passive- males 15…24.
There are lot of unlighted streets in urban settlements. The research of Liikenneturva (1997) showed that 28% of pedestrian accidents would be avoided when reflectors used in dark and twilight areas. 26% of Finnish pedestrians used reflectors on unlighted streets /10/. The use of reflectors among females is fast two times higher than among males in Finland.

The special campaign in Estonian TV and press has risen the share of reflectors’ usage from 8% (1996) to 19% (1998), but this level still remains low when comparing Finland. Specially unsafe is pedestrian who moves in darkness or unlighted on the right hand shoulders of highway and wearing dark clothes without reflectors.

3.5. Wearing of helmet

The mandatory use of motor cycle helmets was introduced in Estonia in 1973 and in Finland in 1977. The mandatory use has been followed fast perfectly. While there are any mandatory for bicyclists the data is not so good. The share of helmet users in Finland has risen from 4% (1990) to some 23% (1998).

3.6. Road users opinions.

The survey of health behaviour made a questionnaire of road users- what should be done to improve the road safety? Every responder could choose only one answer /13, 14, 16/

Table 9
The most important measures of road safety improvement, by road user opinions, %

<table>
<thead>
<tr>
<th>Road safety measure</th>
<th>Estonia, 1998</th>
<th>Latvia, 1998</th>
<th>Finland, 1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of seat belts</td>
<td>6.7</td>
<td>7.1</td>
<td>27.5</td>
</tr>
<tr>
<td>Speed limits</td>
<td>20.7</td>
<td>36.4</td>
<td>13.8</td>
</tr>
<tr>
<td>Building of light traffic routes</td>
<td>11.7</td>
<td>3.3</td>
<td>15.1</td>
</tr>
<tr>
<td>Highway construction</td>
<td>5.1</td>
<td>7.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Traffic counseling</td>
<td>6.7</td>
<td>6.3</td>
<td>19.7</td>
</tr>
<tr>
<td>Increased traffic control</td>
<td>23.7</td>
<td>16.0</td>
<td>11.8</td>
</tr>
<tr>
<td>Higher penalties</td>
<td>3.3</td>
<td>5.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Continuous use of vehicle headlights</td>
<td>1.1</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Improving the quality of training</td>
<td>21.0</td>
<td>16.7</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
<td><strong>100</strong></td>
</tr>
<tr>
<td><strong>Number of answers</strong></td>
<td><strong>1260</strong></td>
<td><strong>2275</strong></td>
<td><strong>3587</strong></td>
</tr>
</tbody>
</table>

The opinions between the Baltic countries and Finland are very different. The three principal measures among Estonians and Latvians are:
- Increased traffic control;
- Speed limits;
- Improving the quality of training.

All three measures are not bounded with road user behaviour but with police, traffic experts and teachers of driving schools.

Same measures among Finns are:
- Use of seat belts;
- Traffic counseling after driving school;
- Development of light traffic routes (there are 4000 km of such routes in Finland already).
Higher penalties, highway construction and continuous use of headlights (what is mandatory in Estonia since 1995 and Finnish rural roads since 1982 and streets since 1997) are considered to be less important measures.

4. CONCLUSIONS

Presented above results indicate remarkable differences between the Baltic and Nordic countries, while split in the motorization ration will decrease year by year.

The Baltic countries have a goal to join the EU in the nearest future and thus must harmonize the transportation situation, including the road safety with other EU countries. The progress and experience of the Nordic countries could be set as an example for the Baltic countries.

The main reasons of insufficient road safety level in the Baltic region are:

- Baltic countries must reduce the number of traffic fatalities and severe injuries. In the first stage the increase of passive safety measures in parallel with speed control (50 kph for Lithuanian urban streets) should be put on the first priority. The cost of these measures is minor.
- The change of road users (especially pedestrians) attitudes towards the road safety should be developed.
- Meaningful sanctions against some drivers, especially novice drivers, playing the main role in safety (speeding, drinking and driving, lack of skills) must be used. The use of error pointing system is under discussion now in Estonia.
- Wrong attitudes of the society in general towards the road safety must be considered as a national health problem.
- Disadvantages in road user training procedures (especially concerning the drivers’ training and children traffic education).
- National Road Safety programmes should discussed widely in society and approved by the parliament.
- Lack of finances for infrastructure development and road safety activities.

The road safety statistical system differs from country to country (also among the Nordic countries), thus the comparison of different aspects is sometimes difficult to consider. An international level of road safety statistic system must be marked out, which allows to make regional, continental and global comparisons.

In last year (1999) the number of road deaths decreased in Estonia from 284 to 232 or by 18.3%, in Latvia from 677 to 652 or 3.7% and in Lithuania from 829 to 748 or 9.8%.
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INTRODUCTION

The traffic situation in South Africa is not satisfactory at all, judging from recent statistics. The news media, radio and television can only portray a partial picture of the actual situation. Only by looking at the statistics a real picture and an understanding of the enormity of the problem can be formed. In short: it is a national problem but has not obtained national priority status among all stakeholders yet.

In order to form a mental picture of the situation we will look at the statistics for 1998. According to the data 641,277 collisions and casualties were reported, 60,794 people were injured and 9,068 died.

Problem statement:

According to statistics there were approximately 13,000,000 learners from Gr1 - 12 at school during 1996. With the situation as it is, there are a number of issues which must be mentioned and which jeopardise TSE.

- Education authorities seem not to realise the necessity and urgency of TSE.
- Traffic Safety Education does not feature clearly in Curriculum 2005. In other words its place is very vague.
- The teachers are not trained in TSE, it is not included in their teacher’s training programme. They will have to have a good background knowledge regarding TSE to recognise and determine its place within the curriculum.
- TSE can be integrated in almost all the learning areas, but if a teacher does not have the knowledge concerning Traffic Safety, he/she will easily overlook the possibility of integrating it.
- There is a great lack of a sense of responsibility with road users and that creates a very poor attitude towards safe participation in traffic. It must also be realised that Traffic Safety Education is more than just rules and regulations of the road, it is all about attitude and a way of life. An attitude that life is precious, an attitude of respect and sharing of the road. And it is also about recognising that we are all road users from the cradle to the grave and that places a great responsibility on each person to use the road with responsibility.
A number of crucial questions arose

It is a known fact that attitudes cannot be changed by legislation, but through constant intensive education. However, education and legislation should go hand in hand.

Questions like these arose:

- How do we reach the approximate 3 892 480 learners in the foundation grades in South Africa with the relevant knowledge, those children who are most vulnerable in traffic, but also
- those who are inaccessible due to distances and remoteness of many schools?
- How can teachers, who have not specifically been trained in TSE, be supplied with the basic background knowledge?
- How can they be empowered to integrate TSE in the learning programmes with the implementation of outcomes based education?

The workshops

The objective was to, eventually, reach the teaching corps and to help them, through the use of teaching materials developed by the National Department of Transport specifically for this purpose, to present Traffic Safety Education in schools.

Initially the Centre for Education in Traffic Safety developed a Traffic Safety Education Workshop programme that was offered to the provinces to empower their traffic safety officials with the basics of TSE and to have an understanding of OBE. The idea was that they should go into their regions and disseminate the knowledge. After the presentation of the first of these workshops, we realised that the ideal would be to reach teachers themselves and to be supported and serviced by trained officials. KwaZulu Natal (KZN) clearly had the same idea and CENETS was approached with a request to conduct workshops in their province.

The workshop programme was well thought through. A contract with Department of Transport of KZN was acquired and the workshops started in May 1999. It was like new shoes. As we got on the way, the going became easier and more relaxed. We had good co-operation from the liaison person allocated to us. He has a good relationship with the Department of Education of KZN, who was very co-operative.

Schools and specific teachers in each region were targeted. Up to four contact sessions or workshops were arranged in a region. Initially one-day workshops were offered, but by popular request the workshops were presented over two days and the programme adapted accordingly. Workshops were often held in remote rural areas that entailed travelling long distances, but usually the scenery was breathtakingly beautiful.

A positive note is that in a number of regions the regional managers welcomed the workshops, they attended and showed their interest, even if it was only an hour or two.

By the end of March 2000 the number of workshops in KZN came to 33 and 900 teachers attended. The feedback received from the teachers, the Department of Transport in KZN, and the CSIR was very encouraging and indicated that teachers were very positive.
The programme

A comprehensive programme was compiled. It included the following:

- Introduction to Traffic Safety Education
- The limitations of the young child in traffic
- Trauma that children experience after involvement in an accident
- The role and effect of alcohol
- Available programmes and media
- A recap of OBE
- STEP within an OBE framework
  - The use of the integration manuals to support STEP
- Other: CITP in OBE
  - The proposed Traffic Safety Education Curriculum

CONCLUSION

The workshops afforded a number of teachers to come in contact with Traffic Safety Education for the first time in their teaching profession. They were supplied with the teaching media. Considering the enthusiasm of most men and women, we trust that they went back to their schools able to integrate TSE and with a feeling that they can do something worthwhile towards the saving of lives and be of value in their communities.
Session 2  Road Safety Audits

Developing H4-safety barriers for Dutch freeways
Alfred Verweij

Road safety improvement supported by road management computer system on the example of a few Polish cities
Tomasz Szczuraszek

Application and development of road safety audit in Indonesia
Mr Lanalyawati

Information and decision support needs for highway safety
Kenneth Opiela
ABSTRACT

A heavy vehicle that crosses the central reserve of a motorway may cause a severe accident. There is a great risk of oncoming traffic running into the vehicle. Many vehicles run the risk to be involved in a crash, resulting in a great number of casualties and big traffic jams on the trunk road network. After some of these accidents had occurred in the Netherlands, a discussion started about the containment level of safety barriers along motorways. This resulted in a project aimed at the development of safety barriers that meet the highest containment level, the H4-level in the European standard EN 1317-2.

After an investigation of existing H4-safety barriers, new designs were made for a rigid steel barrier, a rigid concrete barrier and a flexible steel safety barrier. The rigid barriers are widened versions of existing Dutch barriers: barriers with the so-called 'STEP'-profile. The flexible steel H4-barrier is a fully new design. In cross-section the barrier has the shape of a triangle which stands on one of its angles. If a vehicle runs into it, the barrier will turn over to a certain extent and by doing so it absorbs part of the kinetic energy. The deceleration of a colliding car is expected to be much lower (=safer) compared to that in a collision with a rigid construction.

The designs of the H4-barriers were made in conjunction with crashing car and heavy vehicles simulations with the use of the VEDYAC computer model. The simulations show that the present designs meet the H4-requirements.
1. INTRODUCTION

On November 15, 1995 at about six o'clock in the morning a severe accident happened on the A20 motorway near the town of Rotterdam. A lorry-driver lost control over his vehicle. The vehicle ran into the central reserve, smashed the crash-barrier, turned over and came to a standstill blocking both carriageways. The 22 year-old truck driver died in the crash. Because the accident happened on a vital part of the road network, it caused an enormous traffic jam. Some motorists had to wait for three hours before the police could guide them via secondary roads. Not until noon the traffic in the Rotterdam area was more or less back to normal again.

Accidents like this confront road authorities with the fact that the present safety barriers on motorways in the Netherlands cannot prevent heavy vehicles to cross the central reserve and cause accidents on the other carriageway. Often, when accidents like that occur, discussions start about the present barriers. Questions arise about the need to increase the containment level of safety barriers, about which parts of the trunk road network need extra protection and which types of barriers are the most suitable for this purpose.

The Civil Engineering Division of the Dutch Ministry of Transport started a project focussed on barriers that are able to stop heavy vehicles leaving the carriageway. The project includes the investigation of existing safety barriers and the development of new barriers that are suitable for the Dutch practice. The barriers should meet the requirements of ‘very high containment’ in the European standard EN 1317-2 (containment level H4a or H4b, see table 1 and 2 in the appendix). This implies that the barriers should be able to redirect a rigid vehicle of 30,000 kg at a speed of 65 km/h and an impact angle of 20° (test TB71) or an articulated vehicle of 38,000 kg at the same speed and impact angle (test TB81). In addition the barrier should pass a test to verify the safety for light vehicles (test TB11).

Photo 1-1  Example of an accident in which a heavy vehicle has crossed the central reserve
2. PRESENT DUTCH SAFETY BARRIERS

2.1 Guardrails

Since the 1960's guardrails have been used in the Netherlands along the motorways. This type of crash-barrier has been developed by carrying out a great number of full scale crash tests. Based on the results of these tests and experience with guardrails used in other countries, it is assumed that the Dutch guardrails meet the H2 level in the European standard EN 1317-2. This implies that the guardrail can pass the tests TB51 and TB11. The rail is expected to redirect a bus of 13,000 kg at a speed of 70 km/h and an impact angle of 20°.

The acceleration severity index (ASI) in the test with the passenger car will be below 1.0 (impact severity level A). Because of the flexible behaviour of the guardrail during the crash, an important part of the kinetic energy of the car is absorbed by the movement of the construction, resulting in relatively small risks for the vehicle’s occupants. As the European standard has been established only recently, the Dutch guardrail constructions have not yet been tested according to this standard. However, activities have started to implement the standards for the existing guardrails.

2.2 STEP-barrier

In addition to the guardrails, Dutch road authorities use the so-called 'STEP-barrier'. This is a single slope barrier with a widening - 'step' - at the base. The slope angle is 8.1° (9 gon under the 400 degrees system). The purpose of the step is to reduce vehicle damage in case of minor collisions. The step prevents damage to the body of the vehicle during light collisions at shallow impact angles ('grazes').

STEP-barriers have replaced the traditional barriers with a New Jersey shape. Evaluation studies showed that small cars tend to turn over when colliding into a New Jersey barrier at high impact speeds. Impact tests in Europe as well as in the US indicate that single slope barriers reduce the risk of turning-over accidents considerably.

Concrete and steel versions of the STEP-barrier have been tested to class H2 as specified in EN 1317-2 and appeared to meet the requirements. As expected, the vehicle showed a stable behaviour in the passenger car test (TB11) during the collision. The car did not show a tendency to turn over. The ASI was 1.4, corresponding with impact severity level B (Drift, 1996).

![Figure 2-1  Guardrail, STEP-barrier and a traditional New Jersey barrier](image-url)
Although the barrier meets the requirements of class H2, this impact severity is less favourable than the impact severity in collisions with the more flexible guardrails. The safety risk for the vehicle occupants is larger than in a collision with guardrails. Foreign research confirms the differences in risk between flexible guardrail constructions and rigid barriers (e.g., Martin, 1997). The STEP-barrier should therefore be suitable for the requirements of the situation. STEP-barriers are for example appropriate on roads with heavy traffic and a very narrow central reserve with lighting columns.

3. EXISTING HEAVY VEHICLE SAFETY BARRIERS

One of the first parts of the project was a literature review providing information about existing safety barriers suitable for heavy vehicles (Pol, 1997). The literature review focussed on information about all barriers from Europe, the United States and Japan, developed to redirect heavy vehicles. Information from the European test institutes and manufacturers was also included.

The literature review showed that heavy vehicle safety barriers can be made of either steel or concrete. Concrete as well as steel barriers that are suitable for heavy vehicles have been found. In situations where there is little space available, rigid concrete barriers with a small working width seem the most appropriate. If there is enough space, the more flexible steel barriers seem more appropriate in realising a higher level of safety for the vehicle’s occupants. With regard to costs of maintenance and repair, the concrete barriers are more economical than the steel barriers. Steel barriers sustain more damage after a collision than concrete barriers.

The available heavy vehicle barriers intended for use on embankments, appeared to differ from those used for bridges and viaducts. The safety barriers for embankments are not as massive in design as other barriers, due to differences in the foundations of the barriers and differences in the space available for deflection.

Heavy vehicle safety barriers are higher than current constructions. The minimum height is about 1.2 - 1.3 m. Tests show that a height of about 1.0 m is not sufficient to prevent a turn over of a heavy vehicle. An increased height of the barrier also contributes in controlling the vehicle’s cargo.

Information on the ASI in tests with colliding passenger cars is available of some of the investigated barriers. In all cases the ASI is below the highest permitted value of 1.4 in the European standard (impact severity level B). In 1997 no barriers that meet ASI ≤ 1.0 (level A) have been found.

4. THE REQUIRED H4 BARRIERS

In many cases there is not much space available to put a safety barrier. Especially near the towns in the west of the Netherlands, the central reserves of the motorways are often very narrow. In addition lighting columns often complicate the installation of barriers. Also, on bridges and viaducts the space available for barriers is often very limited.

In situations with not much space available, the Civil Engineering Division decided to develop a rigid H4 barrier with the STEP-profile. Such a barrier should match the present H2 STEP-barrier and have the same advantages regarding colliding passenger cars in comparison with the traditional New Jersey barrier. Impacts should be possible on both sides of the barrier (maximum deflection about 0.80 m) and for reasons of continuity in road design the barrier should be suitable for embankments as well as for bridges.

As was mentioned above, rigid barriers are less satisfactory compared to flexible constructions with regard to the safety risk for vehicle occupants. Replacing present guardrails by a rigid H4-barrier would mean increasing the safety risk in car crashes. Therefore, in addition to the development of a rigid H4 STEP-barrier, the Civil Engineering Division started research into an H4 safety barrier with a more friendly behaviour in car crashes. This barrier should be able to absorb a part of the kinetic energy of a colliding passenger car, in order to meet the impact severity level A, just like the present guardrails (ASI ≤ 1.0).
In this context a combination of two barriers should also be mentioned. If there is sufficient space, it is possible to meet the diversity of requirements of colliding cars and heavy vehicles by using a combination of a guardrail and a rigid high containment construction. The guardrail ensures a flexible behaviour in car crashes, the rigid construction redirects heavy vehicles. Combinations like this are already in use in the Netherlands.

5. WIDENDED STEP-BARRIER

5.1 Geometry

Based on the present H2 STEP-barrier, calculations were made to determine what adjustments would be necessary to meet the H4-requirements. The basis for these calculations is the behaviour of the present H2 STEP-barrier in the TB51 tests. The calculations show that the present versions of the STEP-barrier are not able to resist the forces of colliding heavy vehicles. In order to meet the H4-requirements in a satisfying way, the barrier has to be wider.

The width at the base of the H4 STEP-barrier has been fixed at 750 mm (see figure 5-1). This width is sufficient to cope with the forces exerted on the barrier and in addition this size allows the barrier to be relatively easy combined with the commonly used lighting columns in the central reserve. The profiles at the sides of the impact are similar to the present STEP-barrier. The height of the solid part of the barrier is also similar to the present STEP-barrier (900 mm) resulting in a width at the top of 410 mm. A rail at the top to prevent heavy vehicles to turn over, results in a total height of the barrier of 1200 mm.

5.2 Concrete version

The Civil Engineering Division has designed two types of H4 STEP-barriers: a widened concrete version and widened steel version. The concrete H4 STEP-barrier is a widened version of the present H2 STEP-barrier consisting of prefab elements linked together by a metal plate. The elements are not secured to the ground. The length of the present elements is 6.0 m. For the H4 STEP-barrier this length was reduced to 4.0 m per element. Parts at the base of the H4-barrier are hollow, which makes it possible to produce elements with the same weight as the elements of the H2-barrier, so that they are as easy to handle (using the same crane).

The Dutch Road Research Safety Institute (SWOV) made computer simulations using the VEHicle DYnamics And Crash (VEDYAC) model in order to verify the performance of this H4-barrier design (Pol, 1999). The simulations confirm that the H4 STEP-barrier designed, can meet the H4-requirements. The simulations also show that the displacement of the barrier is largely dependent on the joint connecting the prefab elements. Together with the uninterrupted rail on top of the barrier, this joint should be able to absorb all forces between two elements. The joint used in the present H2 STEP-barrier appears to be strong enough for this purpose, but in that case the deflection of the barrier due to colliding with a heavy vehicle is unacceptable (> 2.0 m in test TB81). By varying the parameters in the simulation model, SWOV has determined what joint is required for the H4-barrier in order to reach an acceptable displacement of about 0.80 m in test TB 81.

5.3 Steel version

The steel H4 STEP-barrier is a widened version of the present steel H2 STEP-barrier consisting of 5.45 m elements secured to the ground. By choosing a width of 750 mm at the base, the steel version of the H4-barrier can be made of the same type of steel (S235) as the present H2 steel STEP-barrier. The thickness of the steel plate and the consoles is also the same.
A critical point in this system is the anchoring of the barrier to the road pavement. There is not much information available on the maximum forces anchor bolts in asphalt can endure. In order to gather more information, SWOV carried out a number of simple loading tests (Pol, 2000). Three types of anchor bolts were tested: two types of adhesive anchors and a mechanical anchor. The anchors consisted of M24 studs with an 8.8 quality rating. The tests show that the SR mechanical anchor (figure 5-2) can absorb forces that are significantly greater than the adhesive anchors. In the tests the maximum tensile force on the SR anchor is about 170 kN (adhesive anchors: about 50 to 70 kN) and the maximum shearing force about 140 kN (adhesive anchors: about 100 kN).
By means of VEDYAC computer simulations, SWOV has determined the forces exerted on the anchor bolts of the barrier in test TB81 (Pol, 1999). Comparing these forces with the results of the loading tests, shows that the SR anchoring is a good option for anchoring in asphalt at the H4 level. Four groups of SR anchors, with four bolts each, are more than sufficient to absorb the forces (maximum tensile force in the simulations: 1600 kN; SR anchors: 4 x 4 x 170 kN = 2720 kN).

6. TWOFOLD RESISTANT IRON ANGLE (TRI-angle)

6.1 Geometry

In contrast with the widened STEP-barriers, the flexible steel H4 barrier is a fully new design. In cross-section this barrier has the shape of a triangle which stands on one of its angles. In its normal position the height is 900 mm. This is relatively low. The barrier does not obstruct the view of the road users. The width of the construction is 1700 mm. The construction is secured to the ground by a hinge (Figure 6-1).

The TRI-angle should have a 'twofold behaviour': flexible for colliding cars and rigid for colliding heavy vehicles. If a passenger car crashes into the TRI-angle, the construction will turn over. By doing so the barrier absorbs a part of the kinetic energy of the car. This flexible behaviour of the barrier during the crash should result in a gradual transition of the car's speed and direction and consequently in a low ASI. A colliding heavy vehicle turns over the construction as well. The heavy vehicle will push one side of the triangle to the ground. In that position the TRI-angle becomes a rigid construction with a height of about 1.2 m. Calculations show that this height is enough to prevent the truck to turn over the construction.

![Figure 6-1 TRI-angle](image)

6.2 VEDYAC-simulations

VEDYAC computer simulations carried out by SWOV (Sluis, 2000) confirm the behaviour as described above. Simulating the car collision corresponding with test TB11, shows a smooth behaviour of the light vehicle. In this simulation the ASI is slightly higher than 1.0. Based on experiences with other simulations and full-scale tests, it may be expected that in a full-scale test of the TRI-angle the ASI will be below 1.0. Simulating a heavy vehicle collision corresponding with test TB81, shows that the TRI-angle can also redirect a vehicle of 38,000 kg. The vehicle does not turn over the construction. The mechanism of turning and moving up the rails at the side of the impact is able to prevent this.
6.3 Prototype

After the simulations a prototype was built, which was used in some simple tests (photo 6-1). The aim of the tests was to get more certainty about the performance of the turning mechanism. Collisions against the barrier were simulated full scale by using a pendulum (photos 6-2). The kinetic energy of the collision in the test was gradually increased.

The tests with the pendulum showed that the turning mechanism is functioning as expected in case of collisions with relatively high kinetic energy. The performance of this mechanism in minor collisions still needs some improvement. The behaviour of the barrier in collisions with small cars does not seem to be sufficiently flexible.
Besides information about the performance of the turning mechanism, the construction of the prototype also provided practical ideas to simplify the construction. At the moment the Civil Engineering Division is using the results to optimise the construction. Full-scale tests according to the European standard are planned for 2001.

7. CONCLUSION

The Civil Engineering Division has designed two types of safety barriers, which are expected to meet the requirements of 'very high containment' (H4) in the European standard EN 1317-2. These are rigid barriers suitable for narrow cross-sections and a flexible barrier. The flexible barrier is more satisfactory in case of car collisions.

Computer simulations show that rigid H4-barriers can be obtained by widening present Dutch H2 STEP-barriers and adding a rail on top. This applies to the present version of the STEP-barrier consisting of prefab concrete elements and to the present steel STEP-barrier. The concrete version - which is not secured to the ground - demands an adjustment of the joint connecting the prefab elements, in order to limit the displacement resulting from a heavy vehicle collision. The steel version requires changes in the construction's anchoring. However, anchoring a H4-barrier to an asphalt pavement is feasible.

The TRI-angle is a promising design for a flexible safety barrier that can meet the variety in requirements in case of collisions of heavy vehicles and (small) cars. This barrier should be able to redirect heavy vehicles and react flexibly in car crashes as well. It is expected that this barrier will meet a higher level of safety for the occupants of an errant vehicle (impact severity level A in the European standard) than the H4 STEP-barriers (level B).
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Sluis, J. van der, De TRI-angel, geleiderail op H4-niveau (The TRI-angle safety barrier at the H4-level; development of a new safety barrier at the H4-level using the VEDYAC simulation program), Dutch Road Research Safety Institute SWOV, Leidschendam, 2000.
Table 1-1 Vehicle impact test criteria according to the European standard EN 1317-2

<table>
<thead>
<tr>
<th>Test</th>
<th>Impact speed km/h</th>
<th>Impact angle degrees</th>
<th>Total vehicle mass</th>
<th>Type of vehicle</th>
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</thead>
<tbody>
<tr>
<td>TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
<td>Car</td>
</tr>
<tr>
<td>TB 21</td>
<td>80</td>
<td>8</td>
<td>1300</td>
<td>Car</td>
</tr>
<tr>
<td>TB 22</td>
<td>80</td>
<td>15</td>
<td>1300</td>
<td>Car</td>
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<td>TB 31</td>
<td>80</td>
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<td>Car</td>
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<td>TB 32</td>
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<td>Car</td>
</tr>
<tr>
<td>TB 41</td>
<td>70</td>
<td>8</td>
<td>10000</td>
<td>Rigid HGV</td>
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<td>15</td>
<td>10000</td>
<td>Rigid HGV</td>
</tr>
<tr>
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<td>20</td>
<td>13000</td>
<td>Bus</td>
</tr>
<tr>
<td>TB 61</td>
<td>80</td>
<td>20</td>
<td>16000</td>
<td>Rigid HGV</td>
</tr>
<tr>
<td>TB 71</td>
<td>65</td>
<td>20</td>
<td>30000</td>
<td>Rigid HGV</td>
</tr>
<tr>
<td>TB 81</td>
<td>65</td>
<td>20</td>
<td>38000</td>
<td>Articulated HGV</td>
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</table>

Table 1-2 Containment levels according to the European standard EN 1317-2

<table>
<thead>
<tr>
<th>Containment levels</th>
<th>Acceptance test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low angle containment</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>TB 21</td>
</tr>
<tr>
<td>T2</td>
<td>TB 22</td>
</tr>
<tr>
<td>T3</td>
<td>TB 41 and TB 21</td>
</tr>
<tr>
<td>Normal containment</td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>TB 31</td>
</tr>
<tr>
<td>N2</td>
<td>TB 32 and TB 11</td>
</tr>
<tr>
<td>Higher containment</td>
<td></td>
</tr>
<tr>
<td>H1</td>
<td>TB 42 and TB 11</td>
</tr>
<tr>
<td>H2</td>
<td>TB 51 and TB 11</td>
</tr>
<tr>
<td>H3</td>
<td>TB 61 and TB 11</td>
</tr>
<tr>
<td>Very high containment</td>
<td></td>
</tr>
<tr>
<td>H4a</td>
<td>TB 71 and TB 11</td>
</tr>
<tr>
<td>H4b</td>
<td>TB 81 and TB 11</td>
</tr>
</tbody>
</table>
ROAD SAFETY IMPROVEMENT SUPPORTED BY ROAD MANAGEMENT INFORMATION SYSTEM ON THE EXAMPLE OF A FEW POLISH CITIES

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1. INTRODUCTION

In Poland a road share in crashes genesis is still understated. It is mainly caused by the way of preparing source data about crashes. Published Polish statistics about crashes are elaborated basing on accident’s cards or crash’s cards prepared by the police and damage notices reported in an insurance company by sufferers. Those source data do not include appropriate information about road influence on the analysed crash, except those cases when the influence is evident for the person preparing the card of road accident, i.e. when the road attributes directly caused the crash.

Source data becoming from the police and insurance companies imply that the share of road attributes among joined causes of crashes in cities is about 5% for crashes and about 10% for collisions. Moreover, disadvantageous weather conditions are noticed in the source data of accidents (about 15% of accidents and about 10% of collisions) – but more as circumstances of crashes genesis than their causes.

Analyses made by the authors imply that in most cases a road share in crashes genesis is hidden and difficult to exact defining. Only thorough cause – effect analysis gives a chance to find those causes. It is obvious that neither a policeman nor a sufferer describing the crash is able to estimate it appropriately (lack of time, no essential preparing). Hence oftenest road causes are not taken into account in the source data. Statistics prepared basing on the data are incorrect.
It implies further negative effects. The mentioned statistics universalization causes publishing false theses about little influence of a road on crashes’ genesis. The false theses are dangerous because they discourage road companies to modernize the road network to improve road safety and, what is worse, they often excuse those designers whose passion is to design without allowing potential, given by the the designs, menace of road safety.

In fact, as the authors estimate basing on detailed analyses of road safety (road road safety) made in some Polish cities, a road – understood widely together with its environment, traffic and weather conditions – directly or indirectly influences rising of most of crashes. Almost always a crash happens as an effect of a human error. However the error is usually implied by the given disadvantageous road situation, also by the given road defect.

There are some frequent road causes of crashes, among the others: insufficient visibility of impact flow, insufficient visibility of pedestrians on and near zebra-crossing, insufficient visibility of an actual sign of traffic lights, illegible geometric arrangement of the cross-road, gaps in a vehicles’ flow not enough for safe walking a zebra-crossing or for safe including to traffic, disadvantageous location of a stop line, very big radius of right turning, improper location of tram stops (in places that drives do not anticipate ) etc.

Detailed analyses of crashes imply also another characteristic conclusion, i.e. there is a big share of non-residents among crashes causers. In some places of the road network the share reaches 50%. Non-residents meanly four times oftener cause crashes than local persons. The main cause of that fact is that non-residents do not know the road network well. They make mistakes mainly in places that are nontypical in the technical and geometric sense, in places with insufficient visibility, high traffic volume that requires high concentration from drivers, in places where it is difficult to find the right way of driving. All of those facts show how important factors a road and its attributes are in a genesis of crashes.

Preparing the detailed cause-effect analyses of crashes, regarding road attributes, is possible only if an appropriate computer system is available and if it includes rich database about crashes, traffic, road and its environment, weather conditions. Beside data complementarily the system asserts safety systematic and automatic analyses and easy access to data and analyses results wrested for many years. Such a system was worked out by the authors and initiated in some Polish
cities. Its name is RMIS (Road Management Information System) [1–3]. In the paper the authors present the system usage for road safety improvement.

2. WAYS OF USING THE COMPUTER SYSTEM TO IMPROVE ROAD SAFETY

The system RMIS was prepared basing on the following applications: MicroStation, MSSQL i MGE. One of the important system’s advantages, that makes it different from other systems applied in Poland, is that it includes information about all crashes, i.e. both about accidents and collisions as well. Moreover it contains detailed information about road infrastructure and traffic. That gives the base for believable statistic analyses.

Crashes’ documentation (photos, films, sketches, reports, etc.), prepared by the police or insurance companies, is the RMIS system’s main source of information about crashes.

Before crashes data are input into the system’s database they are particularly analysed and compared if data become from several different sources of information, especially regarding a place and a sort of the crash.

Many computer applications and catalogues of graphic symbols were prepared for simple data input and for making varied analyses.

Annual „Road Safety Reports” are prepared for cities where the RMIS system has been applied. Those reports contain both general characteristics of safety and detailed estimations of chosen points on the road network. Among the other diagnoses and ways of improving road safety on the chosen places are describe in reports [4–10].

The RMIS system and „Road Safety Reports” are used in those cities to realise many practical purposes (see fig. 2.1). There are for example:

a) estimation of road safety problem’s dimension and basing on it planning of budged resources assigned for improvement an actual road safety condition;
b) the choice of points for modernisation on account to the low road safety level and basing on it planning a professional operations’ scheme for some next years;
c) development of general conception of the road safety improvement in the chosen places assigned to be modernised;
d) development of engineering design of modernisation in the chosen places of the city road network;

e) estimation of effectiveness of operations which goal is to improve a traffic safety condition and basing on it choosing verified ways and means applied to that improvement;

Fig. 2.1 Ways of using the computer system to improve road safety – idea scheme.
f) forming of proper inhabitants’ behaviours in the aspect of road safety by pointing
dangerous places and faults made by road users.

3. GENERAL ESTIMATION OF ROAD SAFETY

General estimation of road safety in a given city is necessary for estimation
of road safety problem’s dimension and basing on it planning of budgeted resources
assigned for an actual road safety improvement.

General estimation of road safety oftenest contains the following characteristics:

♦ Level of road safety in the analysed city against the background of the
whole country, region and other cities, denominated mainly by the
crashes number, crashes heavity and other various road safety indicators,
also by graph of changes of mentioned indicators for particular years.

♦ Number characteristic of road safety conditions. It applies both to the
number of various crashes and to results of the crashes in the whole city,
in particular years, including costs.

♦ Characteristic of changes of particular kinds of accidents and their effects
in particular months, days and hours.

♦ The structure of places of accidents concentration. The structure consists
of the following elements:
  – cross-roads (inlet, collision area, accumulation area, outlet);
  – road sections (sections between points of collisions, entrance and exit of
    possessions, turning area);
  – car parks or other objects.

♦ The structure of reasons of road accidents. This analysis allows the share
of particular main traffic elements (man, road, vehicle) in crashes’
geneses and allows detailed reasons: road users faults, road disadvantages
and disadvantages of vehicles in traffic.

♦ Characteristic of wreckers and sufferers of crashes. They are described
by: dexterity, age and place of living (local or non-resident), sort of
vehicle and kind of road user (pedestrian, bicycler, driver, passenger).
Road safety condition in particular transport zones of the city. The level of road safety in particular city’s zones is denominated by values of adequate road safety indicators taking account of: a number of equivalent crashes (heavity of an accident is its equivalent), a number of crashes with cyclists and pedestrians, a number of crashes with children, an average crashes heavity, an increment of number of equivalent crashes in comparison to the previous year. Those characteristics are elaborated both graphically (as thematic maps) and in tables (as ranking lists sorted by the decreasing value of the road safety indicator). The indicators values refer to 1 km of the network length in the given zone, i.e. to the indicator of the number of equivalent crashes, to the number of crashes with cyclists and pedestrians, and to the number of crashes with children.

Safety of pedestrians. It is described by: changes of number of crashes and their sufferers in particular years, months, week days, and hours, the structure of the crashes concentration, the structure of the crashes reasons, and the list of places on the road network which are the most dangerous for pedestrians.

Safety of cyclists. It is also described by changes of number of crashes and their sufferers in time, the structure of the crashes concentration, the structure of the crashes reasons and the list of places on the road network which are the most dangerous for cyclists.

Safety of children under their way to and from school is described by the analogous attributes as the above ones and moreover by estimation of the children risk level under their way to and from school in particular school zones.

4. ESTIMATION OF THE ROAD SAFETY CONDITION FOR PARTICULAR PLACES OF ROAD NETWORK

The estimation of the road safety condition for particular places of road network is made to choose places requiring modernisation and to develop a professional plan of the road network modernisation for the nearest years.

The road safety level on particular elements of the city road network (cross-roads, sections between nodes, 50 meters long sections, segments of cross-roads) is
described by values of particular road safety indicators, analogous to indicators used for transport zones estimation. The safety level is described from point of view of all road users including pedestrians, cyclists, children. Basing on the above estimation ranking lists of places on the road network sorted by decreasing values of particular safety indicators are prepared. Analogously lists of the most dangerous places, so-called „black spots” for all traffic participants (pedestrians, cyclists, children) are arranged.

Figure 4.1 shows a piece of a graphical presentation of road safety level estimation on the city road network in relation to the number of equivalent crashes (at the section between nodes the number is calculated comparatively for 1 km of the section length).

Figure 4.2 presents the map of black spots on Bydgoszcz city road network (numbers mean the succeeding position at the ranking list of the most dangerous places).

5. DETAILED ESTIMATION OF ROAD SAFETY FOR SELECTED PLACES OF THE CITY ROAD NETWORK

The detailed road safety estimation for selected places on the city road network is necessary to prepare general postulations for a conception of those places modernisation to improve their level of road safety level.

The detailed road safety estimation contains the following characteristics:

- the localisation of the given place on the city road network,
- the map of accidents,
- figure of places of accidents concentration,
- data statement about the number of crashes and values of particular road safety indicators,
- figures illustrating types of accidents, wreckers characteristic, faults oftenest made by wreckers and crashes circumstances in relation to the road (the weather condition in it),
Fig. 4.1. Characteristic of road safety condition on the chosen part of Bydgoszcz basing on the value of the number of equivalent crashes.
Fig. 4.2. The map of most dangerous places on Bydgoszcz city road network.
illustrations of situation plan of the place and details about geometric dissolving,
highness formation of the given place,
traffic organisation (containing horizontal and vertical signs and traffic lights),
location of devices and other objects on the road lane including advertisements,
traffic volumes, traffic way structure and flow structure (allowing all traffic participants),
road dissolving in the analysed place neighbourhood,
visibility characteristic of other road users, traffic lights, signs,
description of road safety level, containing mainly reasons of crashes in relation to road and traffic attributes,
description of road safety improvement containing also general assumption for preparing a conception design of the place modernisation.

Figure 5.1 presents selected graphical characteristics made for detailed road safety estimation of the given place.

Fig. 5.1a. The general map of road accidents (1999)
Fig. 5.1b. The map of accidents concentration (1998 and 1999)

Fig. 5.1c. The map of accidents with pedestrians, cyclist and trams (1998 and 1999)

Fig. 5.1 An example of the detailed road safety description for the cross-road „Fordońskie Roundabout” in Bydgoszcz.
6. DESIGNING THE SELECTED PLACE ON THE CITY ROAD NETWORK

The RMIS system (based on CAD software) enables computer designing the selected place on the city road network. If the exact estimation of road safety condition and directions of general changes for road safety improvement in the given place are known then it is possible to develop the modernisation plan for the given place. Digital maps with scale 1:500 are the base of the designing in RMIS system. The maps include, except details contained in photos, co-ordinates, subterrestrial and terrestrial system of armature, and also horizontal road marking and vertical signs and other devices in road lane. Plans can be designed with the following tools: tools contained in used environmental applications (mainly MicroStation), applications and graphical symbols worked out by the authors of RMIS (e.g. applications and graphical symbols that enable drawing vertical signs and horizontal road marking).

7. ESTIMATION OF MODERNISATION OPERATIONS EFFECTIVENESS

Effectual operations increasing the road safety level need the continuous estimation of raised effects of those operations. As it is known the road safety is a complex problem, mainly with respect to the influence of many indicators not always associated to the road. So it is not easy to find a formula for all dangerous elements on the city road network. Each place on the network has its individual attributes and requires particular approach. Clearly the continuous effectiveness estimation of operations gives the chance to drop incorrect methods and ways of road safety improvement and enables selection of those methods, ways and devices that bring a positive effect such as an increment of the road safety condition.

Effectiveness estimation of undertaken modernisation operations is prepared basing on the value of the indicator WZj of road safety changes:

\[ WZ_j = \frac{W_{j(t+1,t+2)}}{W_{j(t-1,t-2)}}. \]

where:

- \( t \) - the year of modernisation or the period taken to the comparative analysis
- \( W_{j(t+1,t+2)} \) - the synthetic road safety indicator calculated for the element \( j \) of road
network on the base of accident data for the period of at least two years after the modernisation or after the period taken to the comparative analysis,

\( W_{j(t-1,t-2)} \) - the synthetic road safety indicator calculated for the element \( j \) of road network on the base of accidents data for the period of at least two years after the modernisation or after the period taken to the comparative analysis,

\( W_j \) - the synthetic road safety indicator denoting road safety level on the network element \( j \):

\[
W_j = \sum_{x=1}^{i} \frac{W_{x,j}}{\overline{W_x}} ,
\]

\( W_{x,j} \) - the value of the given traffic safety indicator \( W_x \) on the network element \( j \),

\( \overline{W_x} \) - the average value of road safety indicator \( W_x \) for all road network elements.

Dependently on the value of the \( WZ_j \) indicator the following estimation of road safety level’s is assign:

- \( WZ_j > 1.5 \) – aggravation of road safety,
- \( WZ_j < 0.5 \) – improvement of road safety,
- \( 0.5 \leq WZ_j \leq 1.5 \) – no visible changes of road safety.

8. UNIVERSALIZATION OF ROAD SAFETY PROBLEMS IN PRESS

Oftenest articles about road safety presented in widespread press inform about accidents with serious effects, ways of road and traffic management, traffic aggravations implied by roadwork, about detours and other settlements such as transport service, official entertainment. The articles include also readers’ notes about functioning of respective transport devices and traffic menaces.

In two towns where the RMIS system was applied articles devoted to road safety appear as consistent items in newspapers [11]. They apply database of the RMIS system and annual Road Safety Report for the given city. The articles oftenest contain:
− driving condition on several cross-roads, zebra-crossings, sections that have been modernised etc.,
− the oftenest road accidents,
− typical faults made by road users and causing crashes,
− the way of the safe driving, how to pass a cross-road and other difficult place on road network; it regards mainly cross-roads with tram lines and other nontypical dissolving in relation to traffic management,
− the way of safe pedestrians movement,
− behaviours of traffic users in a case of road accident,
− changes in traffic law and others regulations correlated to road safety,
− implementation of regulations in traffic law
− responsibility for road accidents in concrete situations,
− description of the most dangerous places on the road network,
− detail characteristic of the most dangerous places, including ways of road accident avoid.

Above topics regularly broach in local papers is an interesting material for many road users, and mainly for young and not experienced drivers. Those papers have positive influence for correct and safe behaviour of many persons in road traffic.

Literature:


APPLICATION AND DEVELOPMENT OF ROAD SAFETY AUDIT IN INDONESIA

Road Safety on Three Continents
in Pretoria, South of Africa 20 - 22 September 2000

by

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Nawawi Achwan
Directorate General of Regional Infrastructure Development

ABSTRACT

The high rates fatality of road accident in Indonesia has reached nearly ten thousand deaths every year, and it becomes national problem which need serious handling. One of the caused of it, beside the human and vehicle factor is the road and environmental factor. Based on the international research, the contribution of road and environmental factor in an accident is about 24 %, and another factor there is the single factor (4%). The high proportion of the last two factors indicated strong relationship between road and environmental condition with road user to road safety.

On the other side, road development which was built optimally by implementing geometric principles still cause an accident. It shows that the need of other strategies mainly the improvement of road safety condition through applying road safety concept. The strategy namely Road Safety Audit which is aimed to identify the elements of road that has a higher contribution to accident. In general, safety audit can be applied at the road work beginning from feasibility study stage, draft design stage, detailed design stage, pre opening stage and until existing road has been operated.

Furthermore, this paper introduces the concept of road safety audit which will be implemented on existing by pass road in Cirebon.

1. BACKGROUND.

Road construction which was planned through feasibility study often cause accidents problem. It is operated with the weakness and inconsistency in applying geometric principles. Beside that, other factor might be arising such as road environment and road side development that generate pedestrian, and traffic conflict.

Road safety problems on existing road can be eliminated by means of safety concept approach. The strategy used for this purpose is Road Safety Audit in which to identify road elements that potential as a cause of accident. In general road safety audit can be applied at the beginning of planning that is on the feasibility study stage, then on the draft design, on detailed design, preliminary road opening and the stage where the existing road has been operated.

Lastly, the important of applying road safety audit is on the existing road, since most of road sides operated have a serious road safety problems. Therefore, the concept has been developed and applied on existing road, particularly on by pass in Cirebon which has a relevancy in supporting highway programs in Indonesia.
2. ROAD SAFETY AUDIT.

2.1 Objective and Benefit.

Road safety audit is a kind of formal investigation through potential accident and safety performance of road design or existing road by a team of independent auditor that has an adequate qualification on field of road safety, road geometric, traffic engineering, traffic management and traffic accident investigation.

On the whole, road safety audit has the following aims (1) identify potential road safety for road user which was caused from the road project, and (2) preventing and reducing road safety problems. While, the benefit of road safety audit are as follows (1) to prevent or reduce possibility accident on a certain road side, (2) to minimize casualty of accident, (3) to economize a government budget on preventing road accident, and (4) to reduce a road project budget by making the effective of road design which would be much more expensive if it is implemented after a road has been built.

2.2 Procedure of Road Safety Audit.

The overall procedures of road safety audit are as follows:

(1) choosing auditor team,
(2) identify problems background,
(3) applying checking-list of safety audit,
(4) field Inspection,
(5) compile of finding,
(6) suggestion and improvement, and
(7) improving road elements.

2.3 Road Safety Audit Elements for Existing Road.

The important step in applying road safety audit is a checking list. The checking list consist of 10 groups of problem that is started by common problems until complex problems. Each item entered into checking list is a question with a simple answer and its explanation. Substantial problem in the checking list cover 10 types are: (1) general problem; landscaping, sight distance and free road side space, (2) alignment and cross section, (3) intersection, (4) auxiliary lane and turning lane, (5) the organizing traffic signals and street illumination, (6) non-vehicle traffic, (7) traffic signals, (8) delineation, (9) safety fence (10) pavement condition.

3. METHODOLOGY.

3.1 Applying Procedures of Road Safety Audit.

Methodology which was developed in applying road safety audit concept especially for existing by pass road is carried out in the following stages as it is presented in Figure 1.
In general applying procedure of safety audit consist of: (1) counting typical of road geometric that has been implemented, (2) applying safety audit check list to identify road geometric element, land use, and developing road environment which has higher contribution to accident, (3) evaluating the application of checking list in the field and making the result of finding, (4) carrying out on field survey as a follow up of the application of checking list, (5) identifying technical geometric or technical handling of potential accident countermeasure through accident prevention, (6) making report as a recommendation betterment design and improving road design draft.

### 3.2 Accident Prevention.

Accident prevention in the planning and design of new road construction is to eliminate traffic accident and minimized traffic victim. In this concept, beside applying safety road design based on road geometric principles and also applying safety and security by inspecting the safety aspects on road design.

On the whole the safety concept of road design are as follow:

1. adjust road function based on its grade, function and hierarchy.
2. make road access limitation to avoid traffic conflict which has high risk to traffic accident.
3) considerate road geometric principles according to road user need.
4) maintain the ideal speed design, except at a road site which has higher pedestrian activities, where the speed limit is 30 km/hour.
5) Improve road environment condition which is able to minimize human error (ideal sight distance and adequate road side space, etc.).

The strategy to reduce traffic accident can be done by improving or repairing road design, as follows:
1) Improving drivers expectation by preparing road signal facilities.
2) Repairing intersection design.
3) Applying road island and stumbling block.
4) Preparing pedestrian facilities, etc.

4. APPLICATION OF ROAD SAFETY AUDIT

The location of observation of road safety audit is on By Pass site of Cirebon city, comprise of HR Dharsono street and A. Yani street. By Pass Cirebon includes on the road betterment project of the Directorate General of Highways. This project consist of three phases, as follows.

a) Phase 1 : By Pass 1, between intersection By Pass - Tuparev street until intersection By Pass - Parkit street (± 5.6 km).

b) Phase 2 : By Pass 2, between intersection By Pass - Parkit street until intersection By Pass - Kalijaga street (± 1.8 km).

c) Phase 3 : By Pass 3, The intersection of By Pass - Tuparev street.

The priority of this observation is on the section of By Pass 2, including (1) along the road site, (2) Pemuda intersection, (3) Perjuangan access road, (4) Sunyaragi/Evakuasi intersection, (5) Kesambi/Kranggaksan intersection, (6) access road to Harjamukti Bus Station, (7) Rajawali Raya/Ciremai Raya intersection, (8) Parkit access road.

4.1 The result of Check List Application.

The checking list was applied at several observation locations therefore same checking list sets are needed. Part of the field finding can be directly plotted into a simple map (figure 2).

The general finding of the application of road safety audit as the result from identification of road geometric elements can be seen in table 1. Although part of the elements has been prepared, but it still needs to be improved in accordance with road geometric principles and its safety aspects. Furthermore this table indicated elements which has higher potential to traffic accident on the site. Pedestrian problem that is at pedestrian path and crossing facility (8) which has high contribution to traffic conflict and pedestrian. Improvement on pedestrian path and crossing facilities for pedestrian, as a solution to eliminate potentially accident related with pedestrian. The other elements which also has contribution to accident is public transport shelter (7); road marking (6); signaling (5); and also the other elements associated with road geometric design mainly sight distance (5) and intersection design.
<table>
<thead>
<tr>
<th>No.</th>
<th>Problem</th>
<th>Location</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landscaping</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Haphazard parking</td>
<td></td>
<td>✓ ✓</td>
</tr>
<tr>
<td>3</td>
<td>Lightening</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sight distance</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Road side free space</td>
<td>✓</td>
<td>✓ ✓</td>
</tr>
<tr>
<td>6</td>
<td>Marking</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Road signals</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Alignment / curb / road island</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Lay-out / intersection design / access design</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Pedestrian path</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Pedestrian crossing</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Safety fence for pedestrian</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Traffic conflict with pedestrian</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Traffic conflict</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Bus / public transport shelter</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Bicycle route</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>15</td>
<td>Street lightening</td>
<td>✓ ✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Traffic light</td>
<td>✓ ✓ ✓ ✓</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Road edge marking</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
4.2 Main Finding of Road Safety Problem at the By Pass / Kesambi / Kranggaksan Intersection

In the following discussion will be shown general description of safety condition at one of the intersection which has potential contribution to traffic conflict that leads to traffic accident in the location of observation (intersection By Pass/Kesambi and Kranggaksan):

a. Poor intersection, cause a problem on sight distance and road side free space especially from Kesambi street.

b. Intersection design led to tend traffic conflict.

c. Inappropriate placing of traffic light resulted traffic conflict as caused of longer traffic queuing.

d. In accordance with item c above, pedestrian path was too long and often resulting traffic conflict.

e. Inappropriate placing of traffic island which cause a confusing for road user.

f. Poor bus lay design.

g. High pedestrian volume and unorganized public transport on taking/dropping passengers.

h. Lack of pedestrian facilities around intersection, therefore pedestrian uses the road pavement which has high traffic volume.

i. Lack of traffic signals, such as speed warning, priority signals, etc.
Recommendation of safety improvement are as follows:

a. Improving on intersection design especially for ideal sight distance, road side free space and lane acceleration.
b. Relocating of traffic light to shortened vehicle line.
c. Repairing traffic island position so that not confusing to the road user.
d. Preparing pedestrian facilities (pedestrian path, pedestrian crossing) by optimalisation the ideal pedestrian lane.
e. Completing signals (warning speed signals, priority signal, etc.)
f. Preparing bus/public transport shelters.
g. Making safety fence to separate pedestrian from traffic.

5. CONCLUSIONS

General conclusions of road safety audit concept application, are:

a. Road safety audit concept as a systematic and comprehensive technical approach to identify elements which have high contribution to traffic accident.
b. The implementation of road safety audit need to be supported by an independent team which have a good experience in road safety.
c. This approach can be applied effectively to enhance road safety condition on By Pass road in Cirebon city.
d. Simple application with low cost budget and the comprehensive field survey is not needed.

6. ACKNOWLEDGMENT

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BIODATA

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ABSTRACT

Information and Decision Support Needs for Highway Safety

by

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In December 1997, the AASHTO Executive Board endorsed a Strategic Highway Safety Plan that was developed by its Standing Committee on Highway Traffic Safety. This Plan represents a bold step as it envisions a concerted effort across all aspects of highway safety to achieve the ambitious goal of a reduction of 5,000 to 7,000 fatalities per year. This goal is ambitious because there has been only slight fluctuations from the level of about 42,000 deaths per year for more than a decade.

The AASHTO Strategic Highway Safety Plan provides a comprehensive approach to improving highway safety. Topics 21 and 22 of the Plan focus on improving information resources, the development of better decision support systems, and the implementation of effective safety management processes. Strategies under these topics are described below.

Topic 21 - Improving Information & Decision Support Systems

It was recognized in formulating the Plan that safety professionals need improved information and processes to monitor changing highway conditions and safety trends to be more proactive in addressing existing problems as well as emerging threats to highway safety. These threats occur as there are changes in the characteristics of the vehicle fleet, land use patterns, and/or the volumes or mix of traffic.

Good information properly used is a key underpinning of a sound traffic safety enterprise. Drivers with bad driving records need to be rigorously tracked and appropriate measures taken to protect public safety. The how, when, where, and why of crashes need to be recorded and this data made readily available for identify improvement needs and to formulate safety policy. The technology exists to gather, integrate, and utilize information on a wide variety of safety issues. Understanding and using information technology to the greatest advantage is a critical challenge to traffic safety programs nationwide. Important strategies in this arena include:

A - Improve the quality of safety data by establishing programs for quality assurance, incentives, and accountability within agencies responsible for collecting and managing safety data.
B - Provide managers, and users of highway safety information with the resources needed to make the most effective use of the data.
C - Establish a means for coordinated collection, management, and use of safety information among organizations at all jurisdictional levels.
D - Establish a group of highway safety professionals trained in the analytic methods appropriate for evaluating highway safety information.
E - Establish and promote technical standards for highway safety information systems’ characteristics that are critical to operating effective Safety Management Systems (SMS) programs.

Topic 22 - Creating More Effective Processes & Safety Management Systems

Like other complicated endeavors, traffic safety programs need to be managed effectively to perform well. Sound methodology and effective, integrated information systems are essential. Existing systems must be upgraded to provide the basis for assessment of safety in all phases of highway life, from the design to maintenance. Using the information and insights gained, new programs and processes need to be promoted at all levels, but especially the community level.

Experience has shown that local government and community institutions are often more effective at addressing their safety issues that more centralized units of government. This is especially true in the areas of education and enforcement. Community-based coalitions of local government, law enforcement, and interested stakeholders have successfully impacted safety issues. Important strategies in this area include:

A - Communicate the benefits of existing successful Safety Management Systems (SMS).
B - Implement pilot safety audit processes.
C - Promote strong coordination, cooperation, and communication of safety initiatives within each State.
D - Integrate the planning of highway safety programs and highway safety information systems.
E - Establish an ongoing performance measurement system to evaluate the cost effectiveness of safety investments at both project and program levels.
F - Develop and ratify a national safety agenda.
G - Implement community-based safety programs to engage local partners in areas of traffic safety that most affect their daily lives.

While it was recognized that it is difficult to measure the lives that might be saved through these strategies, there is strong consensus that these are a critical element of any effort to improve highway safety.

This paper intends to provide an overview of the current state-of-the-art in safety information, decision support tools, and safety management processes in the U.S. It will highlight efforts under the Plan to implement improved systems. It will review various efforts relative to the strategies cited above including the Iowa National Model, AASHTO efforts to develop a state-of-the-art crash records system as shareware, various GIS-based systems, the FHWA's Interactive Highway Design Model, the concepts for decision support systems that evolved from NCHRP Project 17-12, web-based safety information sources, and various state efforts. The paper will also provide thoughts on the important research and development efforts that will be needed to implement improved systems.

Reference:

Sesion 3  Modelling Driver Behavior for Roadway Design

Traffic Safety – The relative effectiveness of a variety of road markings and traffic control devices
*Rüdiger Lamm*

Road user characteristics and their relation to behaviour and safety
*Richard van der Horst, Henry Stembord, Weil Janssen and Daniel S Turner*

A versatile crash record analysis
*Daniel S. Turner*
TRAFFIC SAFETY - THE RELATIVE EFFECTIVENESS OF A VARIETY OF ROAD MARKINGS AND TRAFFIC CONTROL DEVICES

Lamm, Rüdiger; Zunkeller, Kai; Beck, Anke.

Abstract

Two-lane rural roads frequently reveal safety-related deficiencies. To alleviate this problem, the main author has developed during the last decade a safety concept based on accident research. This concept consists of three safety-related criteria to evaluate, by quantitative measures, critical situations on existing roadway sections with respect to design-, operating speed-, and driving dynamic consistency. Furthermore, these criteria allow to classify new and old alignments according to good, fair and poor design practices.

However, through new research, it can be assumed that the developed safety concept may be superimposed by different kinds of road equipment, for example, road markings traffic warning signs and/or chevron alignment signs. Therefore, the question should be clarified, if and to what extent the road equipment can influence the accident situation and the results of the above mentioned safety concept.

Through field investigations it was found that typical levels of road equipment can be defined as follows:

Level 1 "Road Markings": edgeline marking, solid centerline, broken centerline etc.

Level 2 "Traffic Control Devices": curve warning sign, reverse turn warning sign, hill warning sign, speed limit sign, chevron alignment sign with up to 3 arrows, as well as combinations.

Level 3 "Traffic Control Devices": road equipment which exceeds level 2, for example, multiple chevron alignment signs with more than 3 arrows.

The influence of the three levels of road equipment on the accident rate and the accident cost rate was individually investigated for the design- and operational parameters: pavement width, radius of curve, curvature change rate of the single curve, longitudinal grade and average annual daily traffic. Further investigations dealt with the interrelationships between different levels of road equipment, safety criteria, design classes for good, fair and poor design and the accident situation.

Overall it can be stated that for endangered and dangerous curved sites or sections, level 2 and especially level 3 led to strong reductions, respectively adoptions with respect to accident risk and severity. Therefore, an appropriate application of road equipment levels normally influences traffic safety positively.

However, it is also to note, that curved roadway sections, which are classified by the safety criteria as "good design" in comparison to those, classified as "poor design", represent for poor design still 10 times higher accident rates and accident cost rates than for good design, despite of the application of the most stringent traffic control devices according to level 3. That means, there exist dangerous curve sites, where even level 3-measures are not sufficient for a sound adaption of the accident situation, and redesigns are inevitable.

In conclusion, the developed safety concept has proven to be valid with and without regarding traffic control devices.
TRAFFIC SAFETY - THE RELATIVE EFFECTIVENESS
OF A VARIETY OF ROAD MARKINGS AND TRAFFIC
CONTROL DEVICES

Lamm, Rüdiger; Zumkeller, Kai; and Beck, Anke

1. Fundamentals

Geometric design guidelines have long been the subject of dispute in the literature. Some argue that the guidelines do not present a clear measure for evaluating the safety level of roadways. For instance, when a road goes into operation, the accident experience afterwards is the only indicator for the safety performance of the road. During the planning stage, there is no way to tell what level there is for traffic safety.

Furthermore, it can be stated:

- No one is in a position to state whether or not a driver's discipline was in order before a high accident location, but then failed at that location. When a driver fails at a high accident location, it is often said, that it was his way of driving, which caused the accident.
- When drivers fail a number of times at certain locations, then it becomes obvious that the problem lies, not with the drivers, but mainly with the geometry of the road itself.

Based on many years of investigations in Europe and the U.S.A. for the establishment of the "Highway Design and Traffic Safety Engineering Handbook [1]", numerous basic relationships between highway geometric design, driving behavior, driving dynamics and accident situation could be analyzed. They form the basis for three quantitative Safety Criteria for evaluating accident risk and severity of two-lane rural roads according to good, fair and poor design practices on new and old alignments. Table 1 reveals the quantitative ranges for Safety Criteria I to III.

Of special interest in modern highway geometric design is "Achieving Design Consistency", expressed by Safety Criterion I. That means, the design speed ($V_d$) shall remain constant on longer roadway sections, and shall be tuned at the same time with the actual driving behavior, expressed by the 85th-percentile speed ($V_{85}$) of passenger cars under free flow conditions. This is guaranteed by the good design level of Safety Criterion I in Table 1, that means the difference between 85th-percentile speed and the design speed shall not exceed 10 km/h along the whole observed roadway section.

The 85th-percentile speed shall be consistent along the roadway section, as well. This is guaranteed by the good design level of Safety Criterion II "Achieving Operating Speed Consistency" between two successive design elements (either from curve to curve or from tangent to curve). That means the 85th-percentile speed differences between two design elements also should not exceed 10 km/h for good design practice. Accordingly speed differences between 10 and 20 km/h correspond to fair design levels, whereas speed differences greater than 20 km/h definitely classify poor design for Safety Criteria I and II (Table 1).
<table>
<thead>
<tr>
<th>Safety Criterion</th>
<th>DESIGN CLASSES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GOOD</td>
</tr>
<tr>
<td>I</td>
<td>(</td>
</tr>
<tr>
<td>II</td>
<td>(</td>
</tr>
<tr>
<td>III</td>
<td>(+0.01 \leq f_{RA} - f_{RD})</td>
</tr>
</tbody>
</table>

Table 1: Quantitative Ranges for Safety Criteria I to III [1]

A well balanced driving dynamic sequence of individual design elements promotes a consistent and economic driving dynamic pattern. This is guaranteed by Safety Criterion III "Achieving Driving Dynamic Consistency" for the good design level in Table 1. This Safety Criterion relies heavily on sound driving dynamic assumptions for side friction assumed, depending on the design speed (denoted here as \(f_{RA}\)) and side friction demanded, depending on the 85th-percentile speed (denoted here as \(f_{RD}\)). [1].

Figure 1: Graphical Presentation of the Safety Evaluation Process [1]
Because of space constraints it is impossible to explain the complex procedure of the Safety Evaluation Process. For the interested reader the above mentioned Handbook [1] is recommended for further studies. A typical evaluation of a two-lane rural road by the three Safety Criteria is shown in Figure 1. For example, it can be recognized at once that the critical curve (element 2) corresponds to poor design practices in terms of Safety Criteria I and II, and to fair design in terms of Safety Criterion III. The other road sections of the existing alignment reveal more or less good design practices.

2. Influence of Road Equipment on Traffic Safety

So far, several research studies at the Institute of Highway and Railroad Engineering of the University of Karlsruhe in Germany revealed a good agreement between highway geometric design, safety criteria and accident situation, expressed by the accident rate and the accident cost rate [2, 3]. However, based on the research work of Beck [4] it had to be expected, that besides the design parameters also the road equipment has influence on the accident situation. That means, that a road segment which is identified as "poor design" by the Safety Criteria, may not become conspicuous with respect to the actual accident situation, since appropriate traffic control devices or speed regulations were applied.

Therefore, in the present paper basic relationships between highway geometric design, accident situation and road equipment should additionally be clarified, and through field-investigations it was found that typical levels of road equipment can be defined as follows (Figure 2):

Level 1 "Road Markings": edgeline marking, solid centerline, broken centerline etc.

Level 2 "Traffic Control Devices": curve warning sign, reverse turn warning sign, hill warning sign, speed limit sign, chevron alignment sign with up to 3 arrows, (individual or on one board), as well as combinations.

Level 3 "Traffic Control Devices": road equipment which exceeds level 2, for example, multiple chevron alignment signs with more than 3 arrows, (individual or on one board), as well as combinations with level 2.

For illustrating purposes the recorded traffic signs are presented in Figure 2.

The following investigations include 79 sections of two-lane rural roads with an overall length of 212 kilometers, which consist of 1466 individual elements (curves or tangents). The overall number of recorded "Run-Off-the-Road" accidents and "Deer" accidents was 723.
Figure 2: Recorded Road Markings and Traffic Signs [5]

The influence of the three levels of road equipment on the accident rate and the accident cost rate was individually investigated for the design- and traffic parameters: pavement width, radius of curve, curvature change rate of the single curve, longitudinal grade and average annual daily traffic.
2.1 Pavement Width

Figure 3 reveals the relationships between pavement width, accident rate and accident cost rate for the three levels of road equipment. As can be seen, a U-shaped relationship can be expected, whereby level 3 represents the highest and level 1 the lowest course. Remarkable is the adaptation of the regression curves for levels 1 to 3 in the range between 6.50 m and 7.50 m. Considering the intensifying of road-equipment-measures at critical roadway sections the positive effect especially of level 3 but also of level 2 becomes obvious.

Figure 3: Relationships between Accident Rate and Accident Cost Rate and Pavement Width for the Three Levels of Road Equipment [5]
Based on the similar trends of accident rates and accident cost rates in Figure 3, one can recognize that accident frequencies and -severity are closely connected, at least for the pavement width - a very interesting result. In conclusion it can be stated that for two-lane rural roads especially pavement widths between 6.50 m and 7.50 m represent favorable results regarding the accident situation in general [4] and with respect to the three levels of road equipment [5]. In the following only the results of the accident rate are shown in the graphs, in case they reveal comparable trends with respect to the accident cost rate.

2.2 Radius of Curve

Figure 4 shows the relationships between radius of curve and accident rate for the three levels of road equipment.

It is interesting to find out, that for radii of curve $R < 150$ m level 1 does not play any role, that means only the road-equipment levels 2 and 3 are present in endangered radii of curve-ranges. This indicates that sensible safety devices are used in those endangered roadway sections by the responsible authorities. According to Figure 4 levels 2 and 3 reveal strong decreasing trends, with increasing radii of curve. In this connection level 3 offers significantly more safety in contrast to level 2 up to radii of curve of $R \leq 250$ m. The same is true for the accident severity, expressed by the accident cost rate [5].

![Figure 4: Relationships between Accident Rate and Radius of Curve for the Three Levels of Road Equipment [5]](chart)

According to Figure 4 and the above statements the use of road equipment-level 3 is urgently recommended, at least for radii of curve less than 250 m, while for greater radii up to about 400 m levels 1 and 2 appear to be sufficient.
2.3 Curvature Change Rate of the Single Curve by Lamm, et al. [1]

It was found that the most successful parameter in explaining much of the variability in operating speeds and accident rates is the new design parameter "curvature change rate of the single circular curve with transition curves (CCRₜ)". This parameter describes the design of a curve through the length-related course of the curvature, which appears to be one of the most important variables in operating speeds and accident situations. The typical formula for determining the curvature change rate of the single curve is:

\[
CCRₜ = \frac{(L_{cl1}/2R + L_{cl}/R + L_{cl2}/2R)}{L} \quad 63.700 \text{ [gon/km] (1)}
\]

where, \( CCRₜ \) = curvature change rate of the single curve with transition curves, gon/km

\( L \) = \( L_{cl} + L_{cl1} + L_{cl2} \) = length of curve, km

(length of curve for determining AR and ACR)

\( L_{cl} \) = length of circular curve, m

\( R \) = radius of circular curve, m

\( L_{cl1}, L_{cl2} \) = lengths of clothoids (preceding and succeeding the circular curve), m

63.700 = \((200/\pi) \cdot 10^3\).

Figure 5 shows the relationships between the accident rate and the curvature change rate of the single curve for the three road equipment-levels. Up to about 300 gon/km (this corresponds without considering transition curves roughly to radii of curve of \( R > 220 \text{ m} \)) the regression curves of level 1 and 2 are nearly identical, that means in more critical areas the signing according to level 2 lowers the accident rates down to a classification according to level 1.

![Figure 5: Relationships between Accident Rate and Curvature Change Rate of the Single Curve for the Three Levels of Road Equipment [5]](image-url)
Correspondingly, levels 2 and 3 reveal also a nearly identical course between 300 gon/km and 500 gon/km (R \approx 200 \text{ m} \text{ to } R \approx 130 \text{ m}). Note, in this case the road equipment-level 3 lowers here high safety deficiencies to those comparable to level 2. Field investigations have shown that such a success could be reached especially through the repetition of multiple chevron alignment signs with more than three arrows (individual or more than one board, according to Figure 2). Beginning with \( CCR_S \geq 450 \text{ gon/km} \) (that corresponds roughly without considering transition curves to \( R \leq 150 \text{ m} \)) level 3 reveals significant improvements in contrast to level 2 signing. This leads to the request, that inconsistencies in the alignment have to be either redesigned or reconstructed, at least for \( CCR_S \)-values greater than 450 gon/km. If that is not possible, they should be secured by signing according to level 3, see Figure 6 as an example.

![Figure 6: Curve, Guided by Multiple Chevron Alignment Signs and Guardrails](image)

For example, the equipment of multiple chevron alignment signs and guardrails throughout the curve can significantly improve the optical guidance, especially at night and under wet surface conditions.

Note, that level 2 or even level 3 signing has proved to be able to improve traffic safety, however often not to a level, which would correspond to good design practices according to the discussed Safety Criteria I to III. Therefore, as interim solution signing can be recommended, but normally the reduced accident situation remains nevertheless at a fair or even poor design level and only redesigns combined or not with RRR-strategies promise, if at all "safe" solutions.
2.4 Longitudinal Grade / Traffic Volume

The statements with respect to the parameters "Longitudinal Grade" and "Traffic Volume" reveal less definite results than so far. However, it is to note, that for higher longitudinal grades (≥ 7%) level 3 of road equipment leads to decisively smaller relative accident numbers than the other levels. This could be taken as evidence for the effectiveness of road equipment-level 3 with a sufficient number of multiple chevron alignment signs for an improved optical guidance, since high longitudinal grades are often superimposed by high curvature change rates of the single curve.

Regarding the traffic volume it is interesting to point out, that obviously in the average traffic volume range (AADT = 4,000 to 8,000 veh. per day) critical horizontal alignments exist, which lead to unadapted operating speeds. Thus, even signing according to level 3 still often leads to very high accident rates and accident cost rates. In those cases it can be expected that only by structural measures the accident situation may be improved.

3. Road Equipment and Design (Curvature Change Rate)-Classes

At the Institute for Highway and Railroad Engineering of the University of Karlsruhe three Safety Criteria and a classification for good, fair, tolerable and poor design practices were developed during the last decade (see Chapter 1 and Table 1).

The considerations are based on the new design parameter "Curvature Change Rate of the Single Curve (Eq. 1)" which has proved to be of great influence for the driving behavior and the accident situation [1, 3-5].

<table>
<thead>
<tr>
<th>CCRs/Design Classes [gon / km]</th>
<th>Mean AR* Overall Database</th>
<th>Mean AR Level 1</th>
<th>Mean AR Level 2</th>
<th>Mean AR Level 3</th>
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<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
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</tr>
<tr>
<td>&gt; 180</td>
<td>0.77</td>
<td>0.80</td>
<td>0.84</td>
<td>0.56</td>
</tr>
<tr>
<td>- 360 fair</td>
<td>1.69</td>
<td>-</td>
<td>1.92</td>
<td>1.84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CCRs/Design Classes [gon / km]</th>
<th>Mean ACR** Overall Database</th>
<th>Mean ACR Level 1</th>
<th>Mean ACR Level 2</th>
<th>Mean ACR Level 3</th>
</tr>
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<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>&gt; 35</td>
<td>2.94</td>
<td>2.58</td>
<td>3.16</td>
<td>-</td>
</tr>
<tr>
<td>- 180 good</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 180</td>
<td>5.96</td>
<td>6.59</td>
<td>6.20</td>
<td>4.05</td>
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<tr>
<td>- 360 fair</td>
<td>14.57</td>
<td>-</td>
<td>20.12</td>
<td>12.85</td>
</tr>
</tbody>
</table>

* AR = accident rate [acc./10^6 veh.-km]
** ACR = accident cost rate [German Marks/100 veh.-km]

Table 2: Mean Accident Rates and Cost Rates for Different Design (CCR_s)-Classes and Road Equipment-Levels [5]
In order to get a better overview of the accident situation, the curvature change rate of the single curve was broken down in Table 2 into different design (CCRₜₜ℄)-classes for the existing database of the Master Thesis of Zumkeller [5]. For every design class, a mean accident rate and accident cost rate was calculated. The selected ranges of the CCRₜₜ℄-classes from 180 to 360 gon/km go back to the original investigations in the United States, which were related to the U.S. design parameter degree of curve. The conversion of DC = 5 deg./100 ft. corresponds to CCRₜₜ℄ = 180 gon/km, and of DC = 10 deg./100 ft. to CCRₜₜ℄ = 360 gon/km. The subdivision according to Table 2 was conducted for the overall database as well as for the different road equipment-levels 1 to 3 with respect to the so far used relative accident numbers.

With respect to the relative mean accident numbers in Column 2 of Table 2 for the Overall Database the design (CCRₜₜ℄)-classes could be verified by t-tests with respect to former research work [1, 3, 4, 6] and the same is true for the classification of good, fair (tolerable) and poor design practices according to Lamm, Psarianos et al. [1]. Based on the relationships in Table 2 the following results are found regarding the individual design (CCRₜₜ℄)-classes for the overall database (Column 2):

1. Accident rates and accident cost rates increase significantly with increasing CCRₜₜ℄-classes (Column 2).

2. The CCRₜₜ℄-range up to 180 gon/km represents a relatively low accident risk and a relatively low accident severity and is classified as "good design" [1, 4-6].

3. In the CCRₜₜ℄-range from 180 gon/km up to 360 gon/km accident risk and severity are about twice as high as compared to the design class of up to 180 gon/km. This range is classified as "fair (tolerable) design" [1, 4-6].

4. In the CCRₜₜ℄-range greater than 360 gon/km accident rates and accident cost rates are partially 3 to 4 times higher as compared to the design class of up to 180 gon/km. This range is classified as "poor design" [1, 4-6].

Regarding the road equipment-levels in Table 2 it is to note that level 3 does not exist in the good design range. The same is true for level 1, which does not exist in the poor design range. This is understandable, since normally level 1 is not able to improve poor design practices, and the application of level 3 in the good design range would make no sense. For the investigated equipment-levels (Table 2, Columns 3-5), there always exist increases in accident rates and accident cost rates between the individual design classes compared. That means, that even the strongest road equipment level, for example such one with multiple chevron alignment sings, guardrails, etc. (see, Fig. 6), is not able to influence an originally poor design in such a way, that accident rates and accident cost rates could reach values representing the good design levels, for example, of the overall database (Table 2, Column 2).
Further important results with respect to the superimposition of design classes and road equipment-levels according to the conducted research [5] and Table 2 are:

1. Obviously the individual road equipment-measures are used by the responsible authorities according to the local accident history.

2. There exists a strong superimposition between the design classes (good, fair, poor) and the road equipment-levels 1 to 3.

3. The responsible authorities attempt to compensate increasing endangerments within the individual design classes by a more intensive road equipment-level.

4. The design class "poor" is still decisively more dangerous than the design class "good" (see, Columns 4 and 5), although level 3 has obviously a better impact on the accident development, as compared with levels 1 or 2.

5. On dangerous roadway sections level 3 leads to better results than level 2 with respect to accident risk and accident severity, as Columns 4 and 5 of Table 2 clearly reveals.

Thus, fundamental knowledge could be gained between design (CCR₃)-classes and sensible road equipment-level, in such a way, that for endangered and dangerous curved sites, level 2 and especially level 3 may lead to strong reductions, respectively adaptations with respect to accident risk and severity. Therefore, an appropriate application of road equipment-levels normally influences traffic safety positively.

4. Road Equipment and Safety Criteria

In the last part of this paper the evidence of the results between safety criteria (Table 1) and actual accident situation was examined, based on 9 case studies [5].

As most important result it could clearly be confirmed, that the three quantitative safety criteria are suitable for the classification of roadway sections according to good, fair (tolerable) and poor design practices. In this connection Table 3 proves that relatively low accident rates and accident cost rates can be expected for good design, whereas relatively high accident rates and accident cost rates normally represent poor design practices.

<table>
<thead>
<tr>
<th>Safety Evaluation</th>
<th>AR</th>
<th>ACR</th>
<th>Number of Investigated Curves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good Design</td>
<td>0.23</td>
<td>1.56</td>
<td>69</td>
</tr>
<tr>
<td>Poor Design</td>
<td>1.94</td>
<td>15.81</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 3: Relationships between Good / Poor Design Practices and Mean Accident Rates and Cost Rates for 99 Curved Sections [5]
Note, that curved roadway sections, which are classified by the safety criteria as "good design" in comparison to those, classified as "poor design" represent for poor design still 10 times higher accident rates and -cost rates than for good design, despite of the application of the most stringent traffic control devices according to level 3. Besides, it was found, that curved sections with low endangerment-potential in general are equipped according to level 1, whereas curved sections with relatively high endangerment-potential reveal for the most part traffic control devices according to level 3. Nevertheless, even level 3-road equipment is often not able to sufficiently diminish the danger of accident at critical roadway-sections. That means, that furthermore in those cases redesign-, reconstruction or RRR-strategies are in the forefront for improving traffic safety or the installment of stationary radar devices becomes necessary, for example, to reduce excessive speeds.

5. Conclusion

Considering the afore defined road equipment-levels with respect to individual design parameters and relative accident numbers, it was found that the application of signing and guardrails is obviously conducted by the responsible authorities according to the level of endangerment of the respective roadway section. Especially regarding the new design parameter "curvature change rate of the single curve" with respect to relative accident numbers in Figure 5, the sensible classification of road equipment according to levels 1 to 3 could be confirmed. Furthermore, it was found, that a reasonable signing with traffic control devices leads to an accident reduction. Note, that road equipment-level 3 (often combined with guardrails) is first of all used at very dangerous roadway sections and normally shows positive results.

Overall, with respect to highway geometric design and accident situation the already gained knowledge of the Institute for Highway and Railroad Engineering at the University of Karlsruhe could be confirmed. Both the design (CCR\textsubscript{3})-classes according to Lamm et al. [1-3] and the correspondingly derived safety evaluation process are superimposed by the road equipment-levels. This often leads to a reduction, respectively, to an adaptation of accident risk and accident severity, however certainly not to a weakening or even to a questioning of the developed safety conception. Relevant application of road equipment-measures, especially by reasonable signing and guardrails, normally leads to a positive influence on the accident situation.
Literature Review


Road user characteristics and their relation to behaviour and safety

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Abstract
This paper reviews the available material for the production of a database that should underlie the definition of the so-called ‘design road user’. After considering the basic questions dealing with the incorporation of human factors knowledge into highway design guidelines, an inventory is presented of known dose-effect relationships between road user characteristics on the one hand and behavioural as well as safety parameters on the other. These characteristics are divided into background characteristics (of either a permanent or temporary nature), driver information processing characteristics, and behavioural parameters as they can be observed on the road.

While useful knowledge on several characteristics is already available, the investigation of several variables that may be very relevant has hardly started. Among the latter are:
- **Life-style**, i.e., composite profiles as interrelated patterns of rather mundane characteristics that are more descriptive of an individual than simple uni-dimensional variables.
- **Attentional characteristics**. Of the information-processing functions, attention – the stage preceding the actual processing by the senses – appears to be of central relevance. This pertains, on the one hand, to the ‘Useful Field of View’, and on the other to the capacity to shift attention from one object to another.
- **Decision-making characteristics**. Individuals differ in the way in which they reach decisions. If the situation is risky, the perception of the risk and the thoroughness with which the decision is taken appear to be of prime importance.
- **Driving behaviour parameters**. If safety is a desired outcome of the highway design process it should be known what the accident risks associated with certain driving behaviours are. This can only be the case if quantitative relationships are developed that link behavioural parameters to the ensuing accident probability and/or severity.

1 Introduction

This paper has two parts. In the first we list a number of questions dealing with what it means when we try to incorporate ‘human factors’ into highway design guidelines. The second part focuses on the state of knowledge with respect to specific driver characteristics that could qualify for being incorporated. From this some conclusions follow with respect to what we already know and what are the remaining issues for further research.
2 Basic questions

The following issues appear to be relevant to the incorporation of human factors knowledge, with a bearing on individual characteristics, into highway design guidelines.

2.1 Accommodating different kinds of characteristics

The characteristics of people (i.e. road users) can, for the purpose of this discussion, be divided into three categories (see Fig.1):
- Those that can be changed by training and education.
- Those that cannot really be changed, but can be subjected to selection procedures.
- Those that cannot really be changed, and to which the infra-structural design should be adapted.

We are, of course, only considering characteristics that are relevant to taking part in traffic: that is, which have a demonstrated connection to behaviour, future accident involvement, etc. Deciding to which category a given characteristic belongs should, at least, take the following elements into account:
- Its importance, in terms of its effects on behaviour and accident risk (i.e., the steepness of its dose-effect curve).
- Its distribution in the population.
- Its ‘intrinsic’ changeability.

2.2 Accommodating relevant driver characteristics in highway design guidelines

It seems a straightforward matter to adapt the design to a relevant driver characteristic. For example, if it were established that the 95th percentile of the distribution of standard
deviations of lateral position is 0.25 m at design speed it would be easy to calculate the minimum lane width that would make an involuntary lane exceeding almost impossible. A complicating factor to be mentioned here is the possibility of compensatory behaviour from the driver’s side. For example, if the lane width is extended to accommodate what theoretically is the 95th percentile some drivers may now start driving less carefully, thereby shifting the existing distribution of lateral position. It is difficult to foresee this type of effect and the ramifications it may have, and to anticipate on it.

2.3 Accommodating low or moderate correlations between relevant driver characteristics

A problem occurs when the design of an infra-structural object should be adapted to different relevant driver characteristics at the same time. If these characteristics are only weakly correlated within drivers – that is very often the case – the group that meets all cut-off criteria (such as the 95th percentile) gets smaller with the addition of each next characteristic.

2.4 Accommodating future trends

It is difficult to predict how future driver populations will be composed. For this we are completely dependent on other sciences. Even those, however, will not be able to predict developments for more than a few basic demographic characteristics. Other trends, particularly those that have to do with the introduction of new technology in the traffic system, will also affect driver behaviour. In this area there is some level of agreement among experts on how things will proceed, and what the associated time perspectives are.

2.5 Defining what are the important driver characteristics

There may be two reasons why an individual characteristic is important. First, an increasing ‘dose’ of the characteristic may have an effect that rises at a fast rate, or the effect may already attain a level that is significant in an absolute sense at a relatively low dose.

The second reason is that the distribution of the characteristic in the population may be such that there is an overrepresentation in the critical tail of the distribution. For example, if high age were predictive of an increased accident involvement there would be more reason to worry if there were many people of high age than if there were only a handful. Thus, it is sheer numbers also that can make a characteristic important.

A somewhat provocative standpoint can be taken with respect to the level at which characteristics should be considered: is it really worthwhile to look into, e.g., drivers personality characteristics as contributory factors, or is it enough to just measure behaviour shown on the road as the basis for highway design?
2.6  **Deciding on cut-off levels**

When designing a consumer product it is unavoidable that a certain percentage of the population will have difficulties to use the product. The choice of a cut-off level is, however, a political rather than a scientific one.

2.7  **Deciding what are the appropriate output parameters**

Finally, it should be agreed what it is we want to achieve. In road traffic, this could be:
- Predictable and appropriate user behaviour, in terms of speed, speed variability, lateral position keeping, car following, etc.
- Maximal driver comfort.
- Minimal accident risk.
- Maximal throughput.

3  **An inventory of driver characteristics and their relation to system performance**

On first sight, there hardly appear to exist individual characteristics that have *not* been considered for their connections with driving behaviour or accident involvement. This sounds as if it should now be easy to draw an overall picture of this area. When we attempted to do so (Janssen, Lourens & Göbel, 1998; see also Stembord & In ‘t Veld, 2000) it turned out to be somewhat more diffuse than expected.

![Fig. 2 Ordering of driver characteristics in ‘funnel’ model.](image-url)
In order to structure the findings from the research literature we used a descriptive ‘funnel’ model, in which layer-by-layer various rubrics of human factors (and levels within those) were listed: see Fig. 2. The reasoning is that the background factors of road users, first of all, determine how certain information-processing functions are performed. These in turn lead to certain behaviour on the road that finally results in certain system performance qualities (safety, throughput, comfort).

For all separate characteristics we looked for dose-effect functions as well as population distributions of the characteristic (for the Netherlands). The multiplication of these two curves results in a function relating the percentile of the distribution a given road user is at to the effect, i.e., the performance in terms of behaviour, safety, etc. For many characteristics, however, this ‘ideal’ approach could not be followed because the required data appeared not to be available.

The following is an outline of what appeared to be the prominent patterns in the research literature. In this, we have restricted ourselves to the dose-effect functions, this being the essential first step in tying the evidence together.

### 3.1 Background characteristics and performance

#### Demographic characteristics

<table>
<thead>
<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Age</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Nationality</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Driving experience</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Socio-economic stratum</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Annual mileage</td>
<td>?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Gender.** Men drive significantly faster than women in some conditions (Hendrickx, 1991). Accident involvement is higher for men than for women, in an absolute sense. However, this is reversed when mileage is taken into account (‘Traffic Test’, undated).

**Age.** There is an inverse-Ü relationship between age and accident involvement (Massie, 1995). However, this is moderated by experience (Maycock, 1997). No systematic study relating driving behaviour to age could be traced.

**Nationality.** There are bits of evidence suggesting that nationals driving in other than their own countries experience more than their share in accident involvement, and that this is related to the quality of their driving behaviour (Dostal & Dostal, 1996: data for Germany).

**Driving experience.** This variable has already been mentioned under ‘Gender’, as it interacts with that variable. Experience also affects the quality of driving behaviour (e.g., Kuiken & Groeger, 1991).

**Socio-economic stratum.** The results on this variable are inconsistent and conflicting (e.g., Zlatoper, 1991; Keeler, 1994; Chipman, 1995; Abdallah et al., 1997).
Annual mileage. The final word on the relation of this variable with accident involvement could well have been said by Maycock (1997): "although a high annual mileage increases risk simply through exposure, those who drive more have a lower accident involvement per mile driven". Thus, the resulting curve is negatively accelerating. It has not been traced in what way this is related to actual driving behaviour (Kuiken & Groeger, 1991).

- **Permanent characteristics**

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<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligence</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Field-dependence</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Attitudes</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Life-style</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Sensation seeking</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Handicaps</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Anthropometric variables</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Intelligence. There is no evidence that intelligence is related to road accident involvement, except perhaps at the very low end of the scale (Elvik, 1989).

Field-dependence. This is the aptitude to resist interfering contextual information when looking for a certain visual pattern. It is tested by means of the so-called ‘Embedded Figures Test’. While research has shown that there may be some effects on driving behaviour, there appears to be no relationship with accident involvement (e.g., McKenna et al., 1986; Quimby & Watts, 1981).

Attitudes. A review by Assum (1997) concludes that attitudes are not reflected in relative accident involvement, when due corrections (for age and annual mileage) are applied. We found no reported research on the effects of attitudes on driving behaviour.

Life-style. Tillman and Hobbs in 1949 wrote: ‘A man drives as he lives.’ Judging from recent research there may be more than a grain of truth in this after all. Gregersen and Berg (1994) related certain ‘life-styles’ of young Swedish driver subjects – composite profiles of everyday activities and interests – to their accident involvement. There appeared to be four ‘high risk’ and two ‘low risk’ life-styles, the latter being almost exclusively practised by women. The paper did not report on actual driving behaviour.

Sensation seeking. This is an individual’s inclination to indulge in new, complex and intense experiences, including the willingness to run the associated physical, social, legal and financial risks (Zuckerman, 1994). Modest correlations with several driving behaviour parameters have been found (speeding, close following: Jonah, 1997; Heino, 1996), as well as with accident involvement (Jonah, 1997).

Handicaps. Cardiac and vascular diseases, diabetes, epilepsy, Alzheimer’s disease, and migraine are all long-lasting conditions that have been shown to be associated with disproportionate accident involvement (the degree depending on the specific ailment). Most of this evidence has been summarised by Elvik (1989). For none of these conditions research was found that deals with effects on driving behaviour. For (some types of) brain disorders and for Parkinsonism there is evidence of negative effects on driving behaviour, but there are no reports on accident risk.
Anthropometric variables. There is not much to mention with respect to this category. Presumably, driving an automobile has become so easy in a strictly physical sense, and cabins are so well-designed, that there cannot be much differentiation with respect to driving behaviour or accident risk.

- **Temporary characteristics**

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<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
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<tbody>
<tr>
<td>Alcohol</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cannabis</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Diazepam</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Stress</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Time-of-day</td>
<td>Yes</td>
<td>Yes</td>
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</table>

Alcohol. The behavioural as well as the consequent accident involvement effects of alcohol intake appear to be sufficiently documented by now (e.g., Stark, 1987).

Cannabis. Moskowitz (1986) concludes that there is probably no effect of cannabis intake on the ensuing accident risk. Some aspects of driving behaviour seem to suffer, while other may even get better (Smiley et al., 1986; Robbe, 1994).

Diazepam. The state of affairs seems to be much the same as for cannabis (O’Hanlon et al., 1982).

Fatigue. It is difficult to single out the effect of fatigue from that of other factors, notably time-of-day. An effort by Folkard (1997) to do so resulted in a function of accident risk against time-on-duty that has a local maximum at about 2 to 4 hrs, with a further increase in risk appearing after approximately 12 hrs. A behavioural study by Riemersma et al. (1977) also demonstrated the development of negative effects after 2 to 4 hrs of driving.

Stress. Much of the epidemiological research in this area is weak, because of its retrospective nature and its reliance on self-reports. The research available, however, suggests that there is a significant relationship between life stress and accident risk (McMurray, 1970). There appears to be no systematic research on the effects of stress (levels) on actual driving behaviour.

Time-of-day. According to Folkard (1997) accident involvement has primary peaks at 3 am and 3 pm, which are probably related to circadian rhythms. Secondary peaks are at 2 am, 2 pm, and 9 pm. In a simulator study by Lenne et al. (1997) subjects’ speed choice as a function of time-of-day showed a surprising resemblance to the Folkard cycle.

- **Motives**

There are some isolated findings which show an effect of certain motivational factors on behaviour and/or accident risk. It appears to be particularly well-established that high-risk driving is associated with being in a company or lease vehicle (e.g., Rajalin, 1994).
3.2  Information-processing functions and performance

- **Attention**

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<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divided attention</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Attention shifts</td>
<td>?</td>
<td>Yes</td>
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</table>

*Divided attention.* The capacity for sequential or parallel monitoring of several relevant objects can be expressed as a ‘Useful Field of View’ (Ball et al., 1993). This has been shown to correlate with accident involvement for drivers aged over 55.

*Attention shifts.* The capacity to shift attention swiftly to the next relevant object is regarded by some as an essential element of driving ability. It can be measured by laboratory tests, such as the dichotic listening task (DLT; Gopher & Kahneman, 1971). Modest correlations between these tests and accident involvement have been reported (Kahneman et al., 1973; Mihal & Barrett, 1976; Aviolo et al., 1981, 1985). However, this type of test, consisting in monitoring whether certain sounds are presented in one ear or the other, may not really pinpoint the attention shifts that are most prominent in traffic. The shifts in traffic may be more of a mixture of active inspection of the environment and attention being passively, and involuntarily, drawn by conspicuous objects.

- **Perception**

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<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
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</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Audition</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Motion perception</td>
<td>?</td>
<td>?</td>
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</table>

*Vision.* There is now reasonable agreement that elementary visual parameters, such as static acuity, are not predictive of future accident involvement (Burg, 1967, 1968; Hills & Burg, 1978). Compensation, in the sense of not (being allowed to) taking part in traffic may be of influence here. ‘Higher-order’ characteristics are more properly regarded as aspects of attention (see the previous paragraph). There are relations with driving-related parameters, however, such as identification and readability distances of signs.

*Audition.* We found no literature on the effects of auditory characteristics on driving behaviour or accident involvement.

*Motion perception.* The same is true for this aspect. For example, we have not been able to locate research dealing with an individual’s susceptibility to motion sickness, or other vestibular characteristics, as a factor that might affect his driving capabilities.

- **Cognition**

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<tr>
<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
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</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>?</td>
<td>No</td>
</tr>
<tr>
<td>Risk perception</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Decision making</td>
<td>?</td>
<td>Yes</td>
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</table>
Knowledge. Elvik’s (1989) review summarises the literature by concluding that no relationship has been shown to exist between road user’s knowledge of traffic rules and their accident involvement.

Risk perception. There is some evidence showing that drivers who are slow in recognising imminent dangers will be over-involved in road accidents (Quimby & Watts, 1981).

Decision making. The relevant aspect appears to be the general thoroughness with which people make decisions on their everyday issues. Scores on the self-rated Decision Making Questionnaire (DMQ), which cover this characteristic, are reflected in road accident involvement, according to West et al. (1992) and Parker et al. (1995).

For all three cognitive characteristics considered there does not appear to be research relating the characteristic to actual driving behaviour.

- Motor functions

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<th></th>
<th>Effect on driving behaviour?</th>
<th>Effect on accident involvement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time</td>
<td>?</td>
<td>No</td>
</tr>
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The issue here boils down to whether someone’s quickness of responding to relevant stimuli is related to the quality of his driving performance and/or his future accident involvement. An early review by Goldstein (1962) concludes that this is hardly the case ($r = 0.17$, maximum, over several studies). Compensation, possibly in the form of acting more carelessly when one knows that one is quick in responding, may play a role (cf. the overrepresentation of young male drivers in road accidents).

### 3.3 Behavioural characteristics and system performance

In this category, certain aspects of driving behaviour per se are considered for their capacity of predicting accident involvement.

<table>
<thead>
<tr>
<th></th>
<th>Effect on accident involvement?</th>
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<tbody>
<tr>
<td>Driver type</td>
<td>Yes</td>
</tr>
<tr>
<td>Violations/driver record</td>
<td>Yes</td>
</tr>
<tr>
<td>Behavioural parameters</td>
<td>Yes</td>
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</tbody>
</table>

Driver type. A typology of drivers would exist when a limited number of patterns in relevant parameters were found, and a procedure to assign each and every driver to one and only one of the patterns. Several driver typologies have been developed over the years, including those of Quenault (1966, 1967a,b, 1968 a,b) and Risser et al. (1983). Despite some methodological drawbacks in some of these studies (e.g., no control for exposure) it is probably fair to say that driver type has been demonstrated to be related to accident involvement.

Violations/driver record. Several papers (Mercer, 1989; Peck, 1993; Rajalin, 1994) demonstrate that driver records, in combination with exposure data, are predictive of
accident involvement. It also appears that self-rated violation data are good enough to replace the ‘objective’ data in the driver record (Reason et al., 1990; Parker et al., 1995).

Driving behaviour. It is a central question of traffic safety science what the quantitative functions are relating behavioural parameters (speed, speed variability, lateral position keeping, headways, TTCs, TLCs, etc.) to accident risk (probability and severity, both of single-vehicle and multi-vehicle accidents). Only little exists in the sense of well-developed theoretical frameworks (for speed and speed variability: Nilsson, 1984; Koornstra, 1990; Salusjaervi, 1990).

4 Conclusions

It may not be too apparent from the compressed descriptions given here, but the field is rather bewildering for the sheer number of characteristics investigated and for its heterogeneity in methodologies, statistical treatments, completeness and type of dose-effect functions obtained, etc.

Nevertheless, it is clear that a number of useful effects exist and are waiting to be applied. On the other hand, the investigation of several variables that may be very relevant has hardly started. Among the latter should be counted:

1. Life-style, i.e., composite profiles as interrelated patterns of rather mundane characteristics that are more descriptive of an individual than simple uni-dimensional variables.

2. Attentional characteristics. Of the information-processing functions, attention – the stage preceding the actual processing by the senses – appears to be of central relevance. This pertains, on the one hand, to the ‘Useful Field of View’, and on the other to the capacity to shift attention from one object to another.

3. Decision-making characteristics. Individuals differ in the way in which they reach decisions. If the situation is risky, the perception of the risk and the thoroughness with which the decision is taken appear to be of prime importance.

4. Driving behaviour parameters. If safety is a desired outcome of the highway design process it should be known what the accident risks associated with certain driving behaviours are. This can only be the case if quantitative relationships are developed that link behavioural parameters to the ensuing accident probability and/or severity.

The research to be devoted to any of these variables should result in the following:

- Dose-effect functions for the relevant characteristics. Care should be taken:
  - that the methodologies applied for the separate issues are identical
  - that complete functions are produced, rather than incomplete or dichotomous ones
  - that the estimates of effects are in standardised form, so that they can be compared across the different characteristics.

- Population distributions for the relevant characteristics. While this half of the story has not been discussed in this paper it is sure that they are woefully lacking or incomplete for most of the relevant characteristics. Yet they are absolutely required in order to assess what the ultimate effects of design guidelines will be.
References


The Critical Analysis Reporting Environment (CARE),
A Versatile Tool to Obtain Optimal Accident Countermeasure Strategies

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INTRODUCTION TO CARE

The Crash Analysis Reporting Environment (CARE) is a sophisticated crash record analysis system that is powerful, highly versatile and easily transportable. It was designed specifically to review accident data and to provide user-friendly summaries and reports on topics defined in real time by the user. CARE operates on a desktop computer using the Windows or NT system. It is in the public domain and can easily be downloaded from the WWW (http://care.cs.ua.edu). With simple modifications it can be mated to virtually any crash record database.

Sample Users of the CARE System – CARE has been implemented by state highway agencies in Alabama, Michigan, North Carolina, Tennessee, Iowa and other states. A large number of cities and local organizations utilize CARE as the basis for their highway safety programs. It is also being applied to aviation accident and incident databases for the Federal Aviation Administration, the US Army, and NASA, which illustrates its extreme versatility. It has received several awards, including the 1995 “Administrator’s Public Service Award for Innovation” by the National Highway Traffic Safety Administration.

Basis of Operation – CARE operates on a query system, with the user defining virtually any combination of roadway system types, geographic locations, accident report data items, combinations of data items, etc. The answers can be obtained in tabulations, graphs, and other means. There are other software systems that perform this function, but CARE goes further. Once initial findings are available, it allows additional analysis and even encourages and guides this analysis. For other accident data systems, the analysis usually stops here because additional information cannot be easily obtained since formulating a new set of queries is too time-consuming, too difficult or too challenging for most users. This being the case, valuable information (that could be obtained from the data) is not retrieved, and crucial safety decisions are thus based upon incomplete information. Millions of dollars are wasted creating databases that are incompletely used or that retain latent, erroneous information.

INFORMATION MINING

For maximum success in accident problem identification and evaluation, the analyst should have virtually instantaneous access to all of the data in the database with a full capability to easily retrieve the pieces of information that are most pertinent to a specific analysis. CARE goes beyond even this. It generates proactive statements of data over-representation without the analyst having to specify the query variables. This capability, called information mining (IMPACT), essentially squeezes all of the first-level information out of the database for any given topic (e.g., alcohol, pedestrians, motorcycles, bicycles, restraints, etc.) and displays tabular or graphical visualizations in a prioritized, worst-first format.

The information mining capabilities of CARE include modules that find roadway locations that are extraordinarily high in accident frequency, severity or rate. Two modules have been developed specifically for this purpose: HotSpot and Early Warning. The HotSpot module is discussed in future paragraphs. It examines the state (or city, or county) roadway system by looking for and flagging all locations that fall above a user-defined threshold. Then a graphical representation is
provided to the user, who can visually examine the specified site and adjust its borders depending upon this graphical representation. At that point information mining can be done, or a number of standardized reports can be generated to aid in the countermeasure development process. The Early Warning module has similar capabilities. However, instead of looking for locations that fall out of range for a given time period, this module compares current accident information with previous accident information (in equivalent time periods) and flags all locations that have recent indications of problems.

**CARE LOCATION CAPABILITIES**

To illustrate the capabilities of the CARE HotSpot module, consider Figure 1. This is the standard work screen for crashes that occur on mileposted roadways in Alabama (all State, Federal and Interstate roadways). Potentially hazardous locations called “hotspots” can be determined for any filter (struck trees, injury or worse, alcohol, etc.), for any of the following criteria:

- **Crash Frequency** – The criterion is some threshold frequency in a given segment length (in the example of Figure 1, the criterion is 15 crashes in 0.4 miles).

- **Crash Rate** – The standard Rate/Quality Control method is used to flag all segments (of user-specified length) that fall above a given probability confidence limit level (e.g., 95% of expectation).

- **Early Warning** – By comparing the most recent user-specified time period with the most recent past, major changes in crash patterns (that might signal a problem) are detected.

As a first step, note the graphical portion of Figure 1. The flags represent hotspots selected using one of the above criteria. The computer merely “walks” down the roadway and determines if the specified criterion is met, and if so, it flags the location. All crashes, however, are output for purposes of providing maximum information, and the color of the dot represents the severity. The problem with this approach, however is that the computer is only so smart. For the 15 crashes in 0.4 miles criteria, for example, it must start searching for a new location as soon as it defines an existing one. In the example above this generated two locations in very close proximity (Locations 1 and 2). In addition, there might be times when the particular segment length specification might be too constraining. Extremely sophisticated algorithms could be developed to attempt to accommodate this. However, CARE has been designed to give the user the option to easily redefine locations or even create entirely new ones that are known to be problems but were not flagged by the system.

This is accomplished by moving and elongating an object on the screen that is called “the bucket.” In Figure 1, it is positioned over Locations 1 and 2. The bucket starts out on the left side of the screen and is set to the user-defined segment length as a default value. When needed it can be moved right or left by dragging its “handle” with the left mouse button depressed. This is used to set the left boundary. Then the right mouse button can be used to stretch or reduce the size of the bucket, creating the right boundary of the new or redefined location. The “Modify” or
“Add” buttons immediately above the diagram either modify the current location or add a new location, respectively. The current location is the one selected in the list at the bottom of the screen.

Figure 1 – CARE Analysis by Location

The purpose of this thoughtful exercise is to help the user add, delete and modify locations to ultimately produce a “pool” of locations to be considered for funding. Additional analysis is required, including an on-site investigation, in order to refine this pool and determine the optimal projects for maximum safety improvement. CARE supports this by providing two types of additional information generation: on line and standardized reports.

The on-line reports are identical to those that CARE can generate for any other type of filter. In other words, once a location is defined and selected as current, CARE recognizes it and automatically establishes a filter for it. Thus, as shown by the buttons above the graph, the standard processing options of Frequency, Crosstabs and IMPACT are available on a location by location basis. The “Accident Numbers” button enables the accident numbers for that location to be generated so that hard copy can be retrieved. If an imaging system is available, these numbers would form the links to immediately display the hard copy report on the screen.

Additional features available include the ordering of locations at the bottom of the screen by crash frequency for any of the severity levels given, by total crashes, or by the “ADT Rate”
(crashes per million vehicle miles). This adds a sensitivity analysis component to the on-line analysis so that severity and rates can be considered simultaneously with overall frequency.

RECENT “IMPACT” DEVELOPMENTS

*CARE* has been under continuous development for a number of years. Two of the recent innovations to the IMPACT module, **variable prioritization** and **drilldown**, will be used in an example analysis later in this paper to illustrate the level of sophistication now available. The example utilizes the definitions listed below:

- **Information Mining** – generating information directly from a database without making queries to the database or even knowing what queries are possible. The ultimate goal is to have the database “talk” directly to the decision-maker with a minimum of user requirements. The only current user requirement of *CARE* is called **issue definition**.

- **Issue** – a general subject about which the analyst seeks knowledge. Examples include: alcohol, pedestrian, motorcycle, child restraint use, graduated drivers’ licensing, or any subject that can be defined by a combination of variables in the database. Users do not even have to know what information might be in the database when the issue is defined; they only need to define the subject about which they want information. The goal is to get access to all of the information that exists on that subject in a logical, organized way.

- **Variable Prioritization** – a method of arranging output so that the variables with the highest potential contribution to the goal (in this case, crash reduction) are presented first.

- **Drilldown** – the ability to seize the moment and instantly generate information when an output indicates its availability.

EXAMPLE APPLICATION OF CARE

**Issue Definition Step** – All *CARE* information mining begins with issue definition. The example for this step (and following steps in the analysis) occurred when the 2000 Alabama Legislature considered a bill to impose a graduated driver’s license (GDL) for new drivers under age 21, based on age and experience. Background information from the Alabama crash database was needed to support the GDL initiative, and *CARE* provided that information.

The only analytical step involved is “issue definition” to determine subsets of data to generate information. It is a simple matter to create a *CARE* filter to restrict consideration to given subsets of ages. For example, a new (16-year-old) causal driver would be an obvious subset to compare – but with what? A comparison with all 16-year-old **non-causal** drivers might be enlightening and a good first step. But GDL makes distinctions between 16 and 17-20 year old drivers, and those two age subsets would be a better comparison. If significant differences between these two groups of crashes could be isolated; the analyst would have an excellent handle on this issue. Even better, *CARE*’s capability to quickly repeat analyses can provide even more information by comparing the 17 age group with the 18-20 group; the 18 age group with the 19-20 group, etc.
Analysis Procedure – The first step is to identify filters that will define the subsets related to the issue. This step is trivial and handled by CARE in less than a minute. The intuitive tool for accomplishing this is activated by clicking “Filter” then “Create” and then “Simple” from the CARE main environment menu. In this example, this step is bypassed for brevity. The next step is to select the appropriate filter (if it is not current), using the tool shown in Figure 2.

Figure 2. CARE Select Filter Tool with Age 16 Causal Driver Selected

The “Select Filter” tool is also used by IMPACT (CARE information-mining module) to select the comparison subset. Note its presence (called “17-20 yr old driver”) in the filter list of Figure 2. It has already been created at this point using the filter generation tool.

Once the age-16 causal driver filter is current, the next step is to activate IMPACT. Merely clicking “Analysis,” then “IMPACT” from the main CARE environment does this. Then two options appear. The default “Compare this subset against its complement,” is accepted most of the time. In this case IMPACT will automatically create the comparison filter and move ahead with its analysis. However, in this example, it is desirable to compare the 16 age group with the 17-20 age group, so the other option is selected, “Compare this subset against that defined by another filter.” When this option is chosen, the filter selection tool in Figure 2 re-appears and the user can choose any of the other filters. For this example, the “17-20 yr old driver” filter is chosen. This leads to the IMPACT variable selection tool given in Figure 3.
Sometimes it is desirable to only run a subset of variables, and this tool allows such an analysis. The user may pick any combination of variables as the basis of an IMPACT run. However, true information mining does not require that the user select (or even know) the variables about which he or she should be concerned. Merely clicking the “Select All” button includes them all (in the case of Alabama crash records, this is about 220 variables).

Figure 3. IMPACT Variable Selection Tool

At this point, the reader should note that a “check” has been placed in the “Order output by max gain” checkbox at the lower left corner of Figure 3. This check assures that variable prioritization will be performed. If the default had been used, it would order the variable outputs in their normal sequential ordering as they appear in the database.

Output From IMPACT Module – The detailed description above belabors the process. With very little practice the entire procedure (including filter definition) takes less than ten minutes, with the actual CARE computer processing taking less than four minutes of CPU time on most standard Pentium processors. So several false starts could be run and evaluated to hone in on the true issue.

A part of the output that results from IMPACT is given in Figure 4. IMPACT provides a highly intuitive comparison between the test and control subsets that were created during issue definition. Since it makes this comparison for all variables, if there is information in the database relative to the issue, it will not escape. There is both a tabular and a graphical output. The tabular output is ordered by potential gain (MaxGain, to be defined below) within each variable. The graphical output can be toggled to either MaxGain order or natural order. The graph in Figure 4 is in natural order. The lighter bars (on the left) refer to proportions of the test
subset (in this case, crashes where the causal driver was 16 years old). The darker bars (on the right) refer to proportions of the control subset, which in this case is the 17-20 causal driver age group. The bar chart quickly demonstrates that 16-year-olds have their problems before and after school hours, as compared to their slightly older counterparts. The tabular portion of Figure 4 shows that the most over-represented time is in the afternoon (3:01-4:00 PM), which is also easily visualized on the graph. The 7:01-8:00 AM time period comes in second.

Figure 4. CARE IMPACT Output for GDL Study: Time.

The analysis can be extended and additional information can be gleaned from the data by exploring the tabular headings from Figure 4.

SubFreq – Subset Frequency. The subset is given in the dark horizontal bar at the top of the figure, “16 YR OLD DRIVER” from the 1998 Alabama Accident Data. As an example, a count of 955 is shown for 16-year-old causal crashes between the time of 3:01-4:00 PM.

Sub % – Subset Percentage. The percentage of the subset in this particular cell. The 955 crashes between 3:01-4:00 PM were 16.129% of all crashes caused by 16-year-olds.

OtrFreq – Other Frequency. The frequency defined by the “other” subset, in this case the subset is the “17-20 yr old driver.” As an example, 2113 crashes caused by the 17-20
year-old causal driver subset occurred between 3:01 and 4:00 PM. Because this subset is of a different size, containing a four-year range of drivers, the frequencies are not directly comparable. This is usually the case – rarely do test and control subsets have even numbers of underlying drivers, vehicles, or mileage so the frequencies normally do not provide any meaningful basis for comparison.

Otr % x – Other Percentage. The percentage of the OtrFreq, comparable to the Sub %. As an example, 11.864% is the percentage of the total crashes caused by 17-20 year old drivers. This 11.864% is literally comparable to its 16.129% counterpart, because if these two subsets behaved identically the two percentages would be identical. The fact that the 16.129 exceeds 11.864 demonstrates that a greater-than-expected proportion of 16-year-olds have their crashes at this time.

OverRep – Over-representation. To get a better handle on the degree to which the test proportion exceeds the control proportion, the test proportion is divided by the control metric (e.g., 16.129/11.864 = 1.359). It indicates that the proportion is about 35% greater than expected. An asterisk (*) after the OverRep factor that difference between the two proportions is statistically significant. A normal approximation to the binomial is assumed, and the alpha value is extremely high (0.99). Further, this test is only performed when both proportions have a sample (frequency) size of at least 20. So when the * appears, there is a clear statistically significant difference between the two proportions.

MaxGain – Maximum Gain. This is a function of both the difference between the proportion and the base sample size. The rationale for this metric is that the maximum that can be expected of applying a countermeasure is the net over-representation. For the 3:01-4:00 PM time period, this would be the differential of the 16.129 – 11.864 proportions applied to the 955-crash base. This amounts to 252.53 crashes. The tabular output is sorted on this column, since it provides a metric to determine “the biggest bang for the buck.”

The MaxGain also provides the basis for outputting the variables in a prioritized order (variable prioritization). Note the small box in the upper right quadrant of Figure 4. If the variables were listed in their natural ordering, they would appear as V001, V002, etc. Since the “Order by MaxGain” was specified in Figure 3, the variables that have the highest cumulative positive MaxGain are output first. This relegates non-significant variables to the bottom of the list and lets users focus on the most meaningful information first.

The particular output presented in Figure 4 is the third one in the list that is considered “meaningful.” Several variables will generally come ahead of the meaningful variables; they are the variables used to generate the subset (in this case, they are variables relating to age or highly correlated with it). In this example, they are followed by two other variables, City and Police Agency ORI (highly correlated to city). These are meaningful in the sense that they demonstrate the city concentrations for 16-year-old causal drivers.

The next variable in order of priority is the number of occupants in the causal vehicle, which is
given in Figure 5. This is a very important (and somewhat counterintuitive) variable, since one of the factors under consideration for the GDL is the restriction on the number of occupants under the age of 21.

Figure 5. CARE IMPACT Output for GDL Study: Number of Occupants

It is clear that 16-year-old drivers are over-represented in the higher number of occupants when compared to their 17-20 counterparts. At this point, the analyst might desire to learn the ages of occupants within these vehicles—a straightforward CARE query. Another primary factor to consider is the time of the crash. So both time and occupants are found to be quite significant. At this point it is important not to get so sidetracked with the study that the main point of the CARE demonstration is missed.

As the IMPACT windows scroll upward, a scenario develops to show strong differences between 16 year-old causal drivers and their older counterparts. Each variable contributes to the scenario, identifying those areas where maturity and experience are an asset, and others where aging actually causes a problem (e.g., alcohol causation, which is under-represented at the younger ages). One factor that contributes to this scenario is the “contributing circumstance” variable, which is given in Figure 6. This shows that speeding, failure-to-yield, and driver-not-in-control are the primary factors that diminish significantly with age.
Drilldown Capabilities – The CARE information mining capabilities described above are able to create information automatically, and to identify all information in a database that might be relevant to a given issue. This is because all of the variables of the database are processed. This does not mean that a given IMPACT run squeezes out all of the information that is available; it just reveals that such information exists. Indeed, because of the billions of bits of potential information in any given database, revealing it all at once would be counterproductive. What is needed is an easy way to surface additional information of interest at the point when it is discovered to be available. This process is called drilldown.

Figure 7 presents an example of a significant finding from the GDL example that might trigger a user’s desire for more information. While the variable “gender driver causal” is not high on the priority list, it is a very interesting finding because females are rarely over-represented, and the proportion differential is statistically significant. With such an over-representation, it is only natural to desire some instant research on the subject. In general, females are only over-represented in the 16-year-old causal age group. The example will be extended to find out why.
The analysis is simple. Click on the FEMALE cell as is indicated in Figure 7, and then click the "Why?" button (in the upper right corner). This will reiterate the IMPACT analysis at a lower level where the subset becomes 16 year-old female causal drivers, and the control becomes all of the 16-year-old drivers. This provides a conservative comparison of the 16-year-old females against their male counterparts (conservative because females appear in both subsets). By reiterating the IMPACT at this lower level, an instant scenario is created for female 16-year-old causative drivers.

Figure 8 illustrates that their problems are a failure to yield the right of way as opposed to speeding (in fact, speeding is significantly under-represented). In other words, the analyst inadvertently discovered that the driving problems that females have at age 16 are significantly different from their male counterparts. This information discovery was something that the analyst was not even fishing for when the study began.

Can this be taken further? What about those females who are failing to yield the right of way? Is it possible to learn more about just where this is happening? Again, click the “Fail to Yield ROW” cell and click the “Why?” button, and the answers appear at the analyst’s fingertips (Figure 9). Four maneuvers are over-represented (as shown by the *). In rank order they are left turn, exiting a private road or private property, starting in traffic, and right turn.
Figure 8. Drilldown on 16-Year-Old Female Causal Drivers

Figure 9 illustrates the drilldown example generated to this point. The first drilldown isolated the females, and showed that one of their main problems was in the “failure to yield” contributing factor. The second drilldown was on failure-to-yield, comparing 16-year-old females who failed to yield against all 16-year-old females. This gave the most robust comparison to isolate the problems of females failing to yield. The third drilldown provided the types of maneuvers that the causal drivers were executing when the crash occurred.

All of the outputs generated during this example analysis are not presented in this paper. However, enough information has been reviewed to show that it was easy to establish a scenario. Furthermore, it is very easy to explore any portion of an on-going analysis using CARE’s inherent features.

For the current example, the next drilldown (not shown in the paper) found over-representations in two-car crashes at intersections where Driver 2 was going straight ahead at 31-35 MPH and the causal driver was over-represented while turning left at a speed of 1-5 MPH. This level of detail is extremely difficult to isolate using conventional software.
At this point the example will be terminated; however, readers will be interested to know that the analysis prepared for the Alabama Legislature went further to identify several trends about 16-year-old female causal drivers. It was shown that they have problems at stop signs and traffic signals (as opposed to yield signs), and that the problems were more prevalent in certain cities than others.

CONCLUSION

This paper has been prepared to acquaint the world family of road safety officials with a versatile analytical tool, CARE. The paper illustrated that CARE is practically limitless in its ability to pursue an analysis and to deliver the most-pertinent information to a user (who may be a novice). It is in the public domain, and the software used to perform the example analyses in this paper can be downloaded from the CARE web site [http://care.cs.ua.edu].

CARE goes beyond providing answers to queries – it lets the database pour out its information. No knowledge is required of the underlying data structure, of any database, or of any statistical package. The user does not even have to know the names of the variables in the database. The only requirements on the part of the user are (1) a genuine concern to improve traffic safety, and (2) the ability to formulate an “issue definition” to bring CARE’s potent capabilities to bear on the identified problem.
Session 4  Human Performance, Attitudes, Values and Road Safety

The diminishing effectiveness of speedmonitoring cameras: The case of no enforcement
P.A. Koushiki and Yousef Alhasan

Driving aggression and accommodation towards pedestrian as a function of perceived legitimacy
David Shinar, Ben Gurion

A comment of the definition of aggression and aggressive driving behavior
Truls Vaa

Mortality rates of motorcyclists compared with car occupants
J, Wessel, V. Schneider

Politics, violence and road safety Why are South African roads such dangerous places?
Wendy Watson

Eye movement recording as a tool for accident in depth investigations
Torbjörn Falkmer

Projected highway fatalities involving older drivers in the United States 2000-2020
Don Jones

Stepping stones to a safer community: Reflections of the santa safe community experience
Lynn Vermaak

A self-help traffic safety programme for schools
C. Nkosi

The evaluation of a precautionous action of alcohol and drugs consumption in Britanny
J.P. Assailly
The Diminishing Effectiveness of Speed-Monitoring Cameras:

The Case of No Enforcement

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June 2000
The Diminishing Effectiveness of Speed-Monitoring Cameras:
The Case of No Enforcement

Professor PA Koushki & Dr. Y. Hasan

ABSTRACT

The problem of deteriorating road safety – marked by growing speed limit violations and increasing number of road accidents – was the reason for the installation of speed-monitoring radar cameras at a number of strategic roadway locations in Kuwait in 1995. During the first few post-installation months, drivers’ observation and respect for speed limits, especially in the vicinity of the radar cameras, were obvious: mean traffic speeds at camera sites were significantly below those measured at sections before and after the camera sites. Due to the lack of enforcement of the speed violators, however drivers’ respect for the radar cameras has gradually diminished during subsequent years. Recent measurements of traffic speed reflect very little driver respect for speed limits even at the camera sites. Statistical tests quantify driver disregard for the speed-monitoring cameras. Increased periodical live enforcement of speed limits in the vicinity of radar cameras is strongly recommended.
In January, 1993 the General Traffic Department (GTD) the Ministry of Interior, installed automatic radar cameras to monitor traffic speed at a number of strategic roadway locations in Kuwait. The aim was to lower the number of high-speed violations and consequently reduce road accidents. Recent traffic safety records point to an increase in both the number of violations and the occurrence of road accidents. This paper argues that without live enforcement support and active follow-up of camera-recorded violations, the effectiveness of these cameras in improving road safety is insignificant at best.

Official statistics reveal an alarming growth rate in the number of traffic violations and road accidents in post-invasion years. As presented in Table 1, a continuous and dramatic increase traffic violations such as of high-speed, going-thru-red, driving in the opposite direction, and road accidents has been experienced since 1992. Between 1992 and 1997, the frequency of high speed violations increased by more than 440%; that of going-thru-red, by 99%; driving in the opposite direction by 187%, and road accident by 65%. The effect of increasing dangerous violations on increasing fatalities should also be noted from the data in Table 1. Numerous researchers worldwide have demonstrated the strong causal relationship which exists between high travel speed and the occurrence of road accidents, accident injuries, and fatalities (2, 3, 4, 5, 6, 7). Kuwait's rising accident and speeding rates suggest a serious deterioration in road safety conditions in this small affluent nation.

Countermeasures for reducing high-speed violations include traffic law enforcement and automatic devices such as speed-monitoring radar cameras (8, 9, 10). In industrialized nations the effectiveness of these devices in reducing certain infrequent point - specific types of traffic violations such as red light running (11) and right-angle crashes at intersections (12) has been demonstrated. However, their ability to reduce high speed and other more frequent types of violations is dubious. This is especially true in the oil-rich nations of the Persian Gulf, where law enforcement is weak and the driving behavior of road users is undisciplined and aggressive. Under such circumstances the use of cameras alone as a violation control measure is bound to fail.

As the statistics in the violation section indicated, high-speed violations in Kuwait have continued to increase in spite of the installment of automatic cameras at a number of strategic road network location. A preliminary investigation of the
cameras’ effect on traffic speed violations showed that drivers, once familiar with monitoring locations, slowed down upon approaching the cameras and sped up immediately after (13). The sudden braking action often involved in this speed reduction at camera points has been observed to cause rear-end collisions (14).

This research study was undertaken to achieve the following objectives:

a) What percentage of drivers violate speed limits at roadways equipped with speed-monitoring cameras?

b) Do traffic speeds at, and before or after, the camera sites differ significantly?

c) What has been the effect of time on camera effectiveness?

EXPERIMENTAL DESIGN

Ten automatic speed-monitoring cameras (five pairs, one camera for each direction) were installed by the GTD at five roadway sites. These include two sites on the 5th Ring Road (5th RR), an expressway with 3 lanes per direction and a speed limit of 120 kmh⁻¹; two sites on the 4th Ring Road (a major arterial with 3 lanes per direction and a speed limit of 80 kmh⁻¹; and one site on the Gulf Road, scenic arterial with 3 lanes per direction and a speed limit of 80 kmh⁻¹. Of these 10 installation sites, six were selected for monitoring traffic speed: one pair on Gulf Road; one pair on the 4th Ring Road, and one pair on the 5th Ring Road.

Three terms of two individuals each were trained to measure traffic speed at the selected roadway sites. Speed was monitored simultaneously at both the camera sites and at sites approximately 1 km (0.61 mile) away from the camera for a period of 30 minutes during the morning peak, afternoon off-peak and evening hours. Speed measurements were repeated six times during each period at each site to cover every weekday and Thursday (the first weekend day in Muslim nations), for a total of 18 observations at each site. The six measurements for each daily period (e.g. morning peak) were then averaged to represent the period's overall traffic speed characteristics. In total, traffic speed was monitored for 54 hours at the six camera sites. The study was repeated during two time periods: 1995-96, and 1998-99.
Table 1. Trends in Vehicle Registrations, Violations, and Road Accidents in Kuwait

<table>
<thead>
<tr>
<th>Year</th>
<th>Registered vehicles</th>
<th>Violations</th>
<th>Road Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>High speed</td>
<td>Red signal</td>
</tr>
<tr>
<td>1992</td>
<td>730,833</td>
<td>8679</td>
<td>4931</td>
</tr>
<tr>
<td>1993</td>
<td>741,329</td>
<td>16858</td>
<td>5505</td>
</tr>
<tr>
<td>1994</td>
<td>772,585</td>
<td>22806</td>
<td>5038</td>
</tr>
<tr>
<td>1995</td>
<td>816,471</td>
<td>31422</td>
<td>8773</td>
</tr>
<tr>
<td>1996</td>
<td>821,706</td>
<td>34040</td>
<td>12229</td>
</tr>
<tr>
<td>1997</td>
<td>822,217</td>
<td>47120</td>
<td>9798</td>
</tr>
</tbody>
</table>

Table 2. Sample Traffic Speed Behavior Before, At, and After the Automatic Cameras (1995-96)

<table>
<thead>
<tr>
<th>Speed Monitoring Site</th>
<th>Speed Characteristics (kmh(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Morning</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Gulf Road: Before</td>
<td>80.2</td>
</tr>
<tr>
<td>At camera</td>
<td>64.7</td>
</tr>
<tr>
<td>After</td>
<td>79.6</td>
</tr>
<tr>
<td>4(^{th}) Ring Road:</td>
<td>Before</td>
</tr>
<tr>
<td>At camera</td>
<td>71.6</td>
</tr>
<tr>
<td>After</td>
<td>93.6</td>
</tr>
<tr>
<td>5(^{th}) Ring Road:</td>
<td>Before</td>
</tr>
<tr>
<td>At camera</td>
<td>95.1</td>
</tr>
<tr>
<td>After</td>
<td>115.7</td>
</tr>
</tbody>
</table>
FINDINGS

The minimum sample size required to meet a 95% confidence level with a maximum error level of five percent (\( \alpha = 0.05 \)), is 385 (20). Results of speed-monitoring data showed that the number of measured vehicle speeds during each monitoring period ranged from a minimum of 357 to a maximum of 421, with a mean of 391. In 90.7% of the monitoring periods, the sample size exceeded the minimum sample requirement.

The mean and the standard deviation of the sample traffic speed by time of day and roadway type are presented in Table 2. A number of important points are evident from the data in the table. First, the mean traffic speed measured before or after an automatic camera was consistently higher than that measured at the camera site itself. This shows that the traveling public is generally well aware of the locations of the cameras. Upon approaching a camera, speed limit violators reduced their travel speeds to the level of the posted speed or slightly above, and accelerated immediately after passing the camera site - a fact which was routinely observed during speed monitoring periods. Second, the mean traffic speed in sections past the camera is very close to or even above the posted speed limit in seven out of nine monitoring periods. This fact is a clear indication of the inappropriateness of the choice of speed limit for the sample arterial roadways.

Third, the fact that the mean travel speed is at, or higher than, the speed limit in more than 75 percent of the monitoring periods, points to the inadequacy and ineffectiveness of traffic law enforcement - a common reality in all of the rapidly developing economies of the Persian Gulf region. In a study of driver violation behavior, Koushki and Al-Ghadeer (16) found that during 112 hours of monitoring traffic violations at 16 intersections (stretching over a 3-month period) in Riyadh and Al-Ghaseem, Saudi Arabia, not a single law-enforcing officer was seen at the study intersections. During these hours, more than 11000 violations (of all types) were recorded, and three property-damage road accidents occurred.

The cumulative frequency distribution of the sample traffic speeds measured at the Gulf Road camera sites during the evening period is presented in Figure 1. Nearly 75% of the drivers drove at or below the 80 (kmh\(^{-1}\)) speed limit, both at the camera site and over the kilometer approaching of past the camera. The remaining
Figure 1. Cumulative Frequency Distribution of Traffic Speed at Gulf Road (Evening)
25% violated the speed limit by as much as 20 (kmh\(^{-1}\)) at the camera site, and 40 (kmh\(^{-1}\)) at sections away from the camera - an indication of the inadequacy of law enforcement officials.

It should, however, be pointed out that due to a number of factors, Gulf Road is one of the most (if not the most) heavily observed roadways by traffic police officials in Kuwait, for a number of reasons. First, most of the recreational and related activities (beaches, restaurants, major fashionable supermarkets, etc.), are served by the Gulf Road. Second, it is heavily-utilized by joy-riding youth with their over-capacitated vehicles and loud music, especially in the evening. Third and most importantly, H.H. the Amir and H.E. the Prime Minister both reside on this roadway.

The land-use type and the presence of traffic police officials are thus the main factors contributing to the close similarity of the cumulative speed distribution curves at and away from the Gulf Road camera sites. The last important point concerning the speed data in Figure 1, is that the 85\(^{th}\) percentile traffic speed rule dictates that the speed limit on the roadway should be 10-20 (kmh\(^{-1}\)) higher than the percent 80 (kmh\(^{-1}\)).

The cumulative frequency distributions of sample drivers' speed behavior at the 4\(^{th}\) Ring Road sites are presented in Figure 2. The inadequacy of traffic law enforcement is quite clear from the speed limit violation rates (80 kmh\(^{-1}\)) on this major arterial roadway. First, even in front of the automatic cameras, nearly 25% of drivers violated the speed limit. Beyond the range of the cameras, 45% of drivers drove at speeds higher than the posted limits. At least 10% of drivers drove 20 (km/hr), higher than the posted speed, once past the camera. The 85\(^{th}\) percentile speed rule would clearly justify a speed limit of 100 (kmh\(^{-1}\)) for the 4\(^{th}\) Ring Road. The speed behavior of sample drivers on this major arterial roadway - similar to that of drivers on Gulf Road, again reflects the point-effectiveness (but overall ineffectiveness), of the automatic speed-monitoring cameras in Kuwait.

**Ineffectiveness Test of Significance**

The statistical test of significant difference between two means was employed to test the null hypothesis: \( H_0 : \bar{U}_1 = \bar{U}_2 \), where \( \bar{U}_1 \) and \( \bar{U}_2 \) are the respective means of the sample traffic speeds at the camera site and away from the camera site. The test was
Figure 2. Cumulative Frequency Distribution of Traffic Speed at the 4th Ring Road (Morning-peak)
performed utilizing the following common equation (15):

$$Z_{\left(1 - \frac{\alpha}{2}\right)} * S_{\bar{u}_1 - \bar{u}_2} > (\bar{U}_1 - \bar{U}_2)$$

(1)

where: $$Z_{\left(1 - \frac{\alpha}{2}\right)} = \text{the number of units of standard deviations from the std. normal distribution curve} (Z = 1.96 \text{ at the 95\% confidence limit; } \alpha = 0.05),$$

$$S_{(\bar{u}_1 - \bar{u}_2)} = \left[ S_{1/N_1}^2 + S_{2/N_2}^2 \right]^{1/2}$$

(2)

$$S_1 \text{ and } S_2 = \text{the standard deviations of traffic speeds measured at and away from the camera sites, respectively. } N_1 \text{ and } N_2 = \text{the respective number of sample vehicle speeds at and away from the camera sites.}$$

The result of the analysis - as presented in Table 3, showed that, with the exception of the evening period at the Gulf Road, the hypothesis $$H_0: \bar{U}_1 = \bar{U}_2$$ was rejected at the 99\% significance level for all periods of the day and at all roadway sites. This finding clearly demonstrates the mere point-effectiveness of the automatic cameras in Kuwait, and their overall inability to control driver speed. The behavior of drivers is simple and logical: they learn about the location of the cameras, slow down (sometimes suddenly and dangerously) to a speed within a reasonable range of the posted limit upon approaching these devices, and then speed-up again once past them.

In other words, violating drivers increase travel speed (to a higher level) as soon as they pass the speed monitoring camera. Why? Because they are nearly certain that they will not be penalized. In a person-questionnaire survey of 1071 random drivers in Kuwait, it was found that nearly 89\% of the sample young drivers (25 year or less) were aware of camera locations. Records showed that none of the reported repeated speed violators (either at or away from the camera), was ever summoned by the safety officials or penalized in any way. Experiences in other countries (2) have also shown that without live police enforcement of traffic rules and regulations to augment automatic control devices, their effectiveness is reduced to an insignificant level.
### Table 3. Statistical Test of Significant Difference between the Means of Speed “At” and “After” the Cameras

<table>
<thead>
<tr>
<th>Monitoring Site</th>
<th>Mean(^a) Sample Traffic Speed (kmh(^{-1}))</th>
<th>Std. Dev.(^b) of Traffic Speed</th>
<th>Sample Size</th>
<th>Test(^c) of hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At camera</td>
<td>After</td>
<td>At camera</td>
<td>After</td>
</tr>
<tr>
<td>Gulf Road:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>65</td>
<td>80</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Afternoon</td>
<td>68</td>
<td>78</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>Evening</td>
<td>75</td>
<td>75</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>4(^{th}) Ring Road:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>72</td>
<td>94</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Afternoon</td>
<td>66</td>
<td>86</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Evening</td>
<td>73</td>
<td>84</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>5(^{th}) Ring Road:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning</td>
<td>95</td>
<td>116</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Afternoon</td>
<td>109</td>
<td>119</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Evening</td>
<td>105</td>
<td>112</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

\(^{a}\) rounded figures
\(^{b}\) Sig. at the 99% confidence level, \( \alpha = 0.1 \)

Six speed-monitoring radar cameras were monitored for the speed behavior of drivers nearly 3 years after the initial study. These included the radar cameras at the 5th Ring Road, the 4th Ring Road, and at the King Fahad freeway. Nearly identical results to those of the 1995-96 study were observed from the analysis of the speed behavior of drivers at the camera, and at locations before or after the camera. The 4th Ring Road, which has an inappropriate posted speed limit of 80 Km/hr, experiences the most predominant violations of its speed limit.

As shown in Figure 3, only 37% of the observed drivers at the camera site, drove at or below the speed limit of 80 Km/hr. At the section “after” the camera, this figure was much smaller – 7% drove at or below the speed limit. 50% of the observed drivers “at” the camera site, had a speed of 86 Km/hr or more. The corresponding figure for the section “after” the camera, was approximately 93 Km/hr.

The cumulative distribution of the observed driver speed at the 5th Ring Road sites is presented in Figure 4. The uneven distribution of speeds (usually following a S-shape curve), is more evident from this figure. Although, due to the appropriate choice of speed limit (120 Km/hr), only a few vehicles violated the speed limit, but again, most vehicles at section “after” the camera, drove at higher speed, than did “at” the camera site.

In order to determine whether the difference in speed values, measured “at” and “after” the radar cameras, the mean speed values were again, subjected to a test of significance. As presented in Table 4, at the 4th Ring Road sites, the difference between the measured speeds “at” and “after” the cameras were statistically significant for the three monitoring periods. The same was generally true for the other two freeway study locations.

CONCLUSIONS

The findings of the present study have pointed to the general ineffectiveness of the speed-monitoring cameras in Kuwait. It is argued herein that, as the experiences of others have also shown, the long-run effectiveness of the automatic cameras in enforcing driver compliance with speed limits will be marginal at best unless it is
Figure 3. Cumulative Distribution of Speeds "At" and "After" the Camera (4th Ring Road)
Figure 4. Cumulative Distribution of Speeds "At" and "After" the Camera (5th Ring Road)
<table>
<thead>
<tr>
<th>Camera Location</th>
<th>Observation site</th>
<th>Test of Significance</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At the camera</td>
<td>Before/After the camera</td>
<td>Calculated</td>
</tr>
<tr>
<td></td>
<td>$\bar{X}_1$</td>
<td>$\sigma_1$</td>
<td>$N_1$</td>
</tr>
<tr>
<td>5th R R$^a$</td>
<td>97</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>5th R R</td>
<td>92</td>
<td>12</td>
<td>101</td>
</tr>
<tr>
<td>5th R R</td>
<td>90</td>
<td>17</td>
<td>107</td>
</tr>
<tr>
<td>4th R R$^b$</td>
<td>85</td>
<td>12</td>
<td>100</td>
</tr>
<tr>
<td>4th R R</td>
<td>80</td>
<td>10</td>
<td>84</td>
</tr>
<tr>
<td>4th R R</td>
<td>80</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>King Fahad (Fintas)</td>
<td>90</td>
<td>12</td>
<td>279</td>
</tr>
<tr>
<td>King Fahad (Fintas)</td>
<td>80</td>
<td>12</td>
<td>240</td>
</tr>
</tbody>
</table>

- $^a$ 5th Ring Road
- $^b$ 4th Ring Road
supplemented by continuous live enforcement of traffic laws, and follow-up penalization of camera-recorded speed violators.

Reliance on these devices alone, however, will likely fail to fulfill the improved safety objective for which they were purchased and installed, as this research has clearly demonstrated in the case of Kuwait. The findings of this study hold important implications for the other affluent and rapidly developing nations of the region. The general conclusions of the research study are, then, that drivers quickly become aware of the locations of the automatic speed-monitoring cameras; they reduce speed at the approach to the camera, and increase speed as soon as they pass the camera. Drivers are also nearly certain that their camera-recorded violations of the speed limit, will have no further punitive consequences.

Countermeasures for reducing high speed and other traffic violations generally include the presence of law-enforcement officers, the utilization of automatic cameras with follow-ups of violators, and most importantly, public and driver safety education programs. Due to the shortage of police resources in many communities, and the limited live-enforcement of traffic laws, (police presence), the effectiveness of these automatic devices in achieving their objective of improving road safety is insignificant.

REFERENCES


Driving Aggression and Accommodation towards Pedestrians as a function of perceived legitimacy

David Shinar, Ben Gurion University of the Negev

For Presentation at the 2000 Traffic Safety on Three Continents.

Three studies evaluated the degree to which drivers accommodate pedestrians attempting to cross the street. The legitimacy of the pedestrians’ behavior was evaluated relative to whether or not the attempt was made mid-block vs. at an unsignalized pedestrian crossing at an intersection, the age of the pedestrian, and whether or not the pedestrian was handicapped (on crutches). Approaching drivers’ accommodation behavior was noted in terms of whether they slowed, stopped, honked, or otherwise demonstrated their intent to either give the pedestrian right-of-way or not. The results were consistent with Shinar’s (1999) model of aggressive driving, demonstrating that both legal and social norms affect drivers’ aggression towards and consideration of pedestrians. The studies have implications for both driver and pedestrian education as well as traffic management and urban design.

This research is relevant to Topics 7 (Human Performance and Safety or 9 (Modeling Driver Behavior), 9 (Modeling driver behavior), and 10 (Vulnerable road users).

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Some comments on the definition of aggression and aggressive driving behaviour

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Abstract:

Aggression in traffic, aggressive driver behaviour and its association with road accidents has definitely been put on the agenda in the recent years (Arnett 1996; AAA Foundation 1997; Arnett et al 1997; Lajunen et al 1998; Mizell 1997; Parker et al 1998; Shinar 1998; Underwood et al 1999). Considering these reports, however, some problems arise concerning the definition of aggression and aggressive driving behaviour. One question is to what extent the definitions used are satisfactory in the understanding and study of aggressive driver behaviour.

Several definitions of aggression and aggressive driver behaviour are presented and several aspects are discussed in more detail. These are:

- Emotional aspects, which to a large extent are missing
- The distinguishing between instrumental and emotional aggression.
- The role of threat: Is it only animals that use ‘threatening appearances’?
- The role of intention
- Aggressive driving behaviour vs ‘road rage’

One of the major problems concerning aggressive driving behaviour, and the possible association with accidents in traffic, is to define in a clear way, what ‘aggressive driving behaviour’ actually is. This difficulty may be a reflection of the variation in definitions of aggression proposed by experts in this field. It is hence difficult to give advice to the police on what types of traffic behaviour they should address in their enforcement efforts. European drivers do, however, admit that they engage in close following, tailgating and chasing of other drivers.

Considering the literature on aggressive behaviour in traffic, it becomes quite clear that there are major differences between the USA and European countries, concerning what is regarded as the problem of aggressive incidents. While the USA have been afflicted by shoot-outs and killings of drivers in the road traffic system for quite some time, such episodes seem quite rare in Europe, although some incidents are known in recent years. Judged from the reports the ‘European problem’ with aggressive driving behaviour seem to be more directed towards less severe levels of aggression and violence. On the other hand, no European data collection system or data base are known that records aggressive driving behaviour, or incidents of ‘road rage’.
1. Introduction

Traffic safety researchers, traffic police and road authorities have one main objective in common: Understand why road traffic accidents occur, and find measures to reduce the number of accidents in traffic. Traffic police forces have long asked researchers what kinds of driver behaviour they should give priority in their enforcement efforts to reduce the number of accidents. And traffic safety researchers have for decades tried to relate traffic accident involvement to how an individual driver normally behaves in traffic (Evans and Wasielewski 1982).

Should the police enforce violations of Road Traffic Acts, or should they address other types of behaviour? If considering violations only, what types of violations should be enforced? Given that enforcement resources are limited, and given that the police itself and road authorities are looking for results of their efforts, the view that only violations that have impacts on accidents should be prioritised, have emerged.

Reviewing a considerable amount of evaluation reports on police enforcement activity, only four types of driver behaviour can be said to be firmly associated with the number and severity of traffic accidents (Elvik et al 1997, ETSC 1998). These behaviours are:

- **Speeding**: A reduction of speed, in terms of average driving speed and/or the number of speeding drivers, is accompanied by a reduction in the number of accidents.
- **Drunken driving**: A reduction in the number of drunken drivers, and/or the level of alcohol in the blood, reduces the number of accidents involving drunken drivers.
- **Seat belt use**: Enforcement of seat belt use increases user rates. When user rates increase, the levels of injury decrease. This is especially true for severe levels of injury, in particular fatal injuries.
- **Regulating driving-and-resting time for drivers of heavy vehicles**: Reduces accidents with heavy vehicles.

In addition, there are some evidence that right-of-way and red-light violations are associated with traffic accidents (Chen et al 1995; South et al 1988).

But questions concerning aggression remain: Is there a link between aggression in traffic and traffic accidents? Is aggressive driving a candidate for police enforcement? Will enforcement of aggression in traffic be followed by a reduction in the number of traffic accidents?
2. Definitions of aggression and aggressive driving behaviour

Aggressive driver behaviour has definitely been put on the agenda in the recent years (Arnett 1996; AAA Foundation 1997; Arnett et al 1997; Lajunen et al 1998; Mizell 1997; Parker et al 1998; Shinar 1998; Underwood et al 1999). The issue of aggressive driving have also been among those addressed in the EU-project ESCAPE which was finalized in June this year 2000. Aggressive driver behaviour and its impact on speed choice is also among issues being studied in a research program on driver behaviour models currently running at the Institute of Transport Economics (TØI).

2.1 Definitions of aggression

What is meant by aggression? What do we understand by aggressive driving behaviour? Is there a consensus concerning the understanding of aggression and aggressive behaviour? Definitions of aggression and aggressive driving behaviour is obviously needed. Considering literature in this field, it has become clear that defining aggression is not a straightforward task. Textbooks in psychology and encyclopaedia differ considerably in their definitions of aggression, as do the definitions used in papers and articles on the subject. Consensus cannot be said to have been reached. And several aspects of the definitions used are troublesome.

- The etymologic origin of aggression is the Latin word ‘aggress(are)’ which means to attack (Webster 1994). Webster’s psychological definition of aggression is: ‘Outwardly or inwardly directed, overt or suppressed hostility either innate or resulting from continued frustration’.

- Dollard et al in ‘Frustration and Aggression’ (1939) defines aggression as: ‘A sequence of behaviour, the goal-response to which is the injury of the person toward whom it is directed’.

- A Norwegian dictionary defines aggression as ‘a hostile attitude towards the environment’ (Guttu 1998).

- A Norwegian encyclopaedia defines aggression as ‘an attack, or hostile behaviour that intends to cause pain, injury or the like’ and continues by distinguishing between aggression in humans and aggression in animals (Svartdal 1995):

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1 ESCAPE – ‘Enhanced Safety Coming from Appropriate Police Enforcement – is an EU-project under the 4th Framework Program running from January 1999 to June 2000.

2 A Strategic Institute Program (SIP) on “Driver Behaviour Models” is currently running at TØI. It is financed by the Norwegian Research Council and the Norwegian Public Roads Administration.
In humans: ‘Acts directed towards other individuals, objects, or oneself. Can be expressed in many ways and intensities, from ironic comments, verbal criticism and self-assertion to physical attacks resulting in destruction, injury or homicide’.

In animals: ‘A large part of an apparently aggressive behaviour do not intend to bring about pain or injury in others, but seeks rather to establish dominance by means of threatening appearances’.

- Konrad Lorenz in ‘On aggression’ (1966) defines aggression as: ‘The fighting instinct in beast and man which is directed against members of the same species’.
- Hilgards “Introduction to Psychology”: ‘Aggression is behaviour that is intended to injure another person physically or verbally’ (Atkinson et al 1996).
- Berkowitz (in ‘Aggression: Its causes, consequences and control’ 1993) and Baron & Richardson (in ‘Human aggression’ 1994): ‘Any form of behaviour that is intended to injure someone physically or psychologically’
- Renfrew (in ‘Aggression and its causes’ 1997): ‘Aggression is behaviour that is directed by an organism toward a target, resulting in damage’

2.2 Definitions of aggressive driving and ’road rage’

Some recent studies of aggression in traffic provide completing definitions of aggressive driving behaviour. A new concept has also entered the arena: ‘Road rage’.

- Lajunen et al (1998) define driver aggression as ‘Any form of driving behaviour that is intended to injure or harm other road users physically or psychologically’.
- Martinez/NHTSA (1997) classify aggressive driving as a traffic offence and defines it as: ‘The operation of a motor vehicle in a manner which endangers or is likely to endanger people or property’ while ‘road rage’ is classified as a criminal offence and defined as ’an assault with a motor vehicle or other dangerous weapon by the operator or passenger(s) of one motor vehicle on the operator or passenger(s) of another motor vehicle or vehicle precipitated by an incident which occurred on a motorway’ (definitions cited from Shinar (1998)).
- Mizell/AAA Foundation (1997), defines ‘aggressive driving’ as: ‘An incident in which an angry or impatient motorist or passenger intentionally injures or kills another motorist, passenger, or pedestrian, or attempts to injure or kill another motorist, passenger, or pedestrian, in response to a traffic dispute, altercation, or grievance’. It is also considered ‘aggressive driving’ when ‘an
angry motorist intentionally drives his or her vehicle into a building or other structure or property'.

2.3 Some comments on the definitions

This variety in the definitions is clearly confusing. It is a surprise to find so little consensus in the definitions of ‘aggression’ and ‘aggressive’ as they are concepts we frequently use in our everyday speech. ‘He seemed very aggressive’, ‘an aggressive salesman’, ‘aggressive marketing’ and the like, are comments we use without much hesitation, and without much objections from others when we make our comments.

Emotional aspects are missing

Renfrew (1997) points out that we may get as many definitions of aggression and aggressive behaviour as the number of people we ask. Could it be that the variability experienced among lay persons are reflected by the variability in the definitions proposed by researchers in this field? It is indeed fascinating that aggression, or anger, being one of the basic drives and emotions in human and animal life, for the most part are defined with almost no reference to emotional aspects. Some of the definitions are completely ripped off any emotional content. And anger and aggression certainly are emotions ‘in motion’, so to speak. I would also argue that when we say ‘he seemed aggressive’ then such a comment is based on the emotional quality of his appearance, and identified by the emotions it arouses in ourselves. But we may differ considerably when we attribute labels on certain kinds of behaviour: I may say ‘he behaves aggressively’, another might say ‘he is self-assertive’. We differ in our perceptions of the surrounding world and we differ with regard to sensitivity, i.e. the emotional and cognitive apparatus we use when we classify and judge the behaviour of others. As said, the variability seen in the definitions proposed, could be reflections of the variability in man’s perceptions of others and the behavioural and emotional categories we use when appraising the behaviour of others.

Baron and Richardson (1994) and Berkowitz (1993) distinguish between instrumental and emotional aggression. Instrumental aggression refers to instances in which the aggressor uses aggressive behaviour as a means of non-injurious goals, rather than out of a desire to harm other people. In emotional aggression, the primary aim of the aggressor is to cause suffering and harm to the victim. This distinction is questionable because it presupposes that instrumental aggression is a kind of behaviour that is free from any emotional content. This is unlikely, emotions are always an aspect and a part of behaviour, even if this is not stated explicitly (Damasio 1994): An individual using aggressive behaviour as a means of ‘achieving non-injurious goals’ would experience emotional satisfaction of his achievement, it could indeed be the working reinforcement that increases the probability of behaviour. A person being used as an instrument for others, and for the achievement of other peoples goals, does not experience any good feelings
when being used, unless perhaps s/he is a masochist or a person who experience their submissive nature with good feelings. It is hence argued that there is no real difference between instrumental and emotional aggression, there is only an apparent difference in the emotional intensity that may be visible to the outside observer.

Some definitions mention that aggression could involve psychological harm or verbal injury of others. Such concepts must also be understood in terms of emotions and cognition i.e. the self-destructive thoughts and painful feelings that may be the results of ironic comments and verbal criticism from others.

*The role of threat: Is it only animals that use ‘threatening appearences’?*

I find it surprising and remarkable that only one of the definitions mentions threats as a part or aim of aggression, and only among animals. Svartdal made a specific remark concerning aggression in animals (1995):

‘A large part of an apparently aggressive behaviour [in animals] do not intend to bring about pain or injury in others, but seeks rather to establish dominance by means of ‘threatening appearences’.

It may look like threats, or acts perceived as threats, are not part of the communication acts between human individuals. But of course it is, man has developed a wide repertoire of communication acts that may induce some kind of fear or perceived as threatening by others: Raising a voice, a hostile glance, indulge in personalites, aggressive questioning, certain body postures and facial expressions. A lot of communication acts induce threats or imaginations of threats, and are hence perceived as aggressive by others.

Threatening interactions are certainly found in road traffic also. Hostile and angry glances are found in traffic as well as outside, but there is more, for example:

* • High speed among vulnerable road users is in itself threatening, making pedestrians and cyclists giving way to the vehicles.
* • Cars ‘diving’ into a crossing in high speed, makes other drivers submissive.
* • Drivers using their larger size of their vehicle in order to make other drivers submissive.
* • When a vehicle come close to another from behind and flashes its headlights repeatedly in order to make a slower vehicle in front change from the left to the right lane so that passing can take place.

Is this aggressive acts? Or is this just normal interaction between two parties were the roles of being self-assertive and submissive are found in a natural way in the process of solving everyday conflicts in traffic? When should acts be regarded as normal interactions and when as aggressive interactions? When and where to distinguish between the two? Where is the cut-off point?
The role of intention

Some road users, and especially drivers, do behave in dominant or threatening ways in order to achieve submission by the other, but again: When is it aggression? The aggressive content of threatening behaviour may be very obvious to the common road user who is exposed to the behaviour in question – i.e. that the act is perceived as threatening and aggressive by the other party, who in turn react with submission. Is the behaviour then aggressive behaviour?

Lajunen et al (1998) argue that the motive or intention of harming other road users should be the criteria that distinguishes aggressive driving behaviour from just reckless, hazardous or dangerous driving. The question is whether this criteria is sound as it relies on (access to) the emotional and cognitive content of the aggressor. An aggressor may deny any intention to harm others although it may obvious to observers that the act was aggressive. It may be argued whether a definition of aggression should include the judgement of observers, i.e. the possibility of external observers to reach intersubjective agreement on whether an act should be classified as aggressive or not.

Road rage

‘Road rage’ is a new concept, entering the arena of road traffic around 1997. In my view, road rage as it is defined earlier, is nothing else than acts of violence, i.e. criminal offences, not traffic offences. And as acts of violence it is nothing new in the society as such, what is new is that violence is now also taking place on the roads as they have done in other sectors of the society for years. There are also indications that this phenomenon is increasing in the USA. The phenomenon must be viewed as part of a much larger and older problem: The problem of violence in modern societies as a whole.

3. Aggression in road traffic

Considering the literature on aggressive behaviour in traffic, it becomes quite clear that there are major differences between the USA and European countries concerning what is regarded as the problem of aggressive incidents. While the USA have been afflicted by shoot-outs and killings of drivers in the road traffic system for quite some time, such episodes seem quite rare in Europe, although some incidents are known in recent years. Judged from the reports the ‘European problem’ with aggressive driving behaviour seem to be more directed towards less severe levels of aggression and violence. On the other hand, no European data collection system or data base are known that records aggressive driving behaviour, or incidents of ‘road rage’, as the one established in the USA by Mizell and the AAA Foundation (described in section 3.2).
3.1 European studies

Several studies have investigated aggressive driving and aggressive acts in road traffic in recent years (Sample Surveys Ltd 1996; Lex Report of Motoring 1996; Joint 1995; Parker et al 1998; Lajunen et al 1998; Underwood et al 1999). Table 1 gives a summary of some frequencies/prevalences of aggressive driving in the UK.

Table 1: Reports on aggressive acts in the UK: Sample characteristics, behaviour reported, frequencies/prevalences.

<table>
<thead>
<tr>
<th>Study and country</th>
<th>Sample</th>
<th>Prevalence of aggressive behaviour types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Surveys Ltd, 1996 (UK)</td>
<td>Car drivers, lifetime prevalence experience</td>
<td>‘Bullied’ when driving: 49%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Verbally abused: 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physically assaulted: 2%</td>
</tr>
<tr>
<td>Lex Report of Motoring (1996) (UK)</td>
<td>Drivers, preceding 12 months</td>
<td>Gestural or verbal abuse: 44%</td>
</tr>
<tr>
<td>Joint (1995) (UK)</td>
<td>Members of UK Automobile Association, last 12 months (n = 526).</td>
<td>‘Road rage experiences’: 90%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Close following/tailgating: 62%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drivers admitting ‘loosing their temper’: 60%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Headlight flashing: 59%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obscene gestures: 48%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physically assaulted: 1%</td>
</tr>
<tr>
<td>Parker et al (1998) (UK)</td>
<td>Self selection sample/Advertising (n = 270)</td>
<td>Chasing others, showing hostility towards others, annoying others by using the horn 89%</td>
</tr>
</tbody>
</table>

3 Referred to in Lajunen et al, 1998
Considering table 1 it is clear that aggressive communication between drivers do take place in the road system in the UK. There is also some consistency across studies: Verbal abuse and obscene gestures are experienced by some 40 – 48% of the drivers, and 1 – 2 % of the drivers have been physically assaulted. But using their horn, showing hostility, receiving gestures, and being verbally abused, can hardly be said to be a problem of traffic safety. Being physically assaulted could be acts of violence, and as such criminal offences, not traffic offences. So what’s in it concerning traffic safety? It is hard to tell from these data, but, lot of UK drivers, 62%, reports close following/tailgating (Joint 1995).

Lease Plan is an international cooperation which organises and finances company cars for larger companies in five European countries: UK, Spain, France, the Netherlands and Norway (Lease Plan Norway 2000). In 1999 Lease Plan made a survey among company car drivers in each of the five countries. The final sample consisted of 1750 respondents – 350 from each of the countries. About 10% of the final sample were female drivers. A part of the survey addressed aggressive behaviour in traffic: Table 2 sums up the opinions of the drivers:

<table>
<thead>
<tr>
<th>Question/Country</th>
<th>Great Britain</th>
<th>Spain %</th>
<th>France %</th>
<th>TheNetherlands %</th>
<th>Norway %</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acted aggressively against other drivers? *</td>
<td>55</td>
<td>54</td>
<td>57</td>
<td>35</td>
<td>68</td>
<td>54</td>
</tr>
<tr>
<td>Obscene gestures? **</td>
<td>66</td>
<td>42</td>
<td>56</td>
<td>51</td>
<td>59</td>
<td>55</td>
</tr>
<tr>
<td>Verbal abuse? **</td>
<td>50</td>
<td>60</td>
<td>57</td>
<td>30</td>
<td>29</td>
<td>46</td>
</tr>
<tr>
<td>Dangerous driving? **</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td>19</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>Chasing car in front? **</td>
<td>7</td>
<td>6</td>
<td>9</td>
<td>11</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Physical assault? **</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Seriously threatened by other drivers? *</td>
<td>41</td>
<td>16</td>
<td>46</td>
<td>33</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

*) All drivers (n = 1750)

**) Subsample: Responded ‘Yes’ to acting aggressively against other drivers (n = 942)

On the average, 54 % of all the drivers admit that they have acted aggressively against other drivers. The percentages of drivers in Great Britain, Spain and France are all of the same magnitude, while Dutch drivers are far below and Norwegian drivers above this average. It is interesting to observe that there is a mismatch between acting aggressively and being seriously threatened by others for Spanish and Norwegian drivers, but not for drivers of other countries. It is hard to tell why, drivers may have different opinions of what ‘serious threats’ are, but it remains strange that this mismatch is reported in traffic cultures that are
quite different. Only French and British drivers reports, and admits, physical assaults, and again there is consistency across studies for the British drivers.

Concerning traffic safety issues, it is more serious that 8% of the drivers admitting aggressive acts also reports ‘chasing car in front’. This average of 8% seems quite stable across the countries, while there is more variation concerning the number of drivers admitting ‘dangerous driving’. The numbers are quite high in Norway and the Netherlands and considerably lower in Spain, France and Great Britain.

3.2 American studies

No studies are found that makes it possible to compare frequencies of aggressive driving in European countries to figures in North America - i.e. ‘aggressive driving’ in the same meaning as the types presented in tables 1 and 2. The recording of aggressive driving have, however, been sampled by Mizell in a report to the American Automobile Association (AAA). The definition of aggressive driving is here different from the ones used in the previous tables and may show an elevated level of violence on American roads (Mizell 1997). Mizell gives descriptions of several traffic incidents:

• Massachusetts – 20th February 1994: Donald Graham (54) and Michael Blodgett (42) had an ongoing, heated dispute chasing each other for several kilometres before ‘.. they both pulled over to an access road and got out of their vehicles. At that point Graham retrieved a powerful crossbow from his trunk and murdered Blodgett with a razor-sharp 29-inch arrow’.

• Seattle, Washington: Terence Milton Hall (57) shots and kills Steven Burgess (21) ‘…. because he was unable to disarm the loud anti-theft alarm on his jeep’

• Washington D.C – April 1996: Nakal Keval Terry (26) and Billy Canipe (26) ‘… began duelling in their cars as they drove up the George Washington Parkway. Travelling at speeds of up to 80 miles per hour, the cars crossed the median of the parkway and hit two oncoming vehicles. Only one of the four drivers involved in the crash survived; Nakal Terry was sentenced to 10 years in prison for his role in the incident’.

Mizell presents several other incidents in line with the ones cited above and gives examples of some of the causes of the aggressive acts:

• ‘He… was killed because he drove too slowly’,

• a woman was shot ‘because the bitch hit my new Camaro’,

• a child was injured because her father ‘cut me off’.
Mizell, who owns a corporation that maintains databases of crime reports, was commissioned by the AAA Foundation for Traffic Safety to search for and collect data on all incidents of violence that involved traffic altercations and use of the vehicle as a weapon. The incidents in Mizell’s database on aggressive driver behaviour, included only the most violent confrontations, i.e. those which were so extreme that they resulted in a police crime report or a published newspaper article. However, the AAA Foundation says ‘they undoubtedly represent a small fraction of the total number of such incidents’ (AAA Foundation 1997).

From January 1990 to 1st September 1996, there were at least 10.037 incidents of aggressive driving in the United States reported to Mizell and Company (Mizell 1997, table 3).

Table 3: Known incidents of aggressive driving that occurred from 1st January 1990 to 1st September 1996 (From Mizell 1997)

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>Increase from previous year (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1129</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>1297</td>
<td>14.8</td>
</tr>
<tr>
<td>1992</td>
<td>1478</td>
<td>14.0</td>
</tr>
<tr>
<td>1993</td>
<td>1555</td>
<td>5.2</td>
</tr>
<tr>
<td>1994</td>
<td>1669</td>
<td>7.3</td>
</tr>
<tr>
<td>1995</td>
<td>1708</td>
<td>2.3</td>
</tr>
<tr>
<td>1996</td>
<td>1201</td>
<td>5.4 *</td>
</tr>
<tr>
<td></td>
<td>10.037</td>
<td></td>
</tr>
</tbody>
</table>

*) The database did not comprise the four months September-December of 1996. Based on the preceding 8 months, an estimate for the whole year 1996 would be approximately 1800 incidents or 5.4 % increase from 1995.

At least 218 men, women and children are known to have been murdered and 12.610 injured as a result of these 10.037 incidents. The 12.610 injuries include cases in which people suffered from paralysis, brain damage, amputation and other seriously disabling injuries (Mizell 1997).

The data gives a yearly average of 1.505 incidents. Estimating the population of the USA to about 260 million, the incidence, i.e. the number of new incidents per year, would be about 5.8 per million citizens per year.

Considering the EU/EEA countries, with an estimated population of 375 millions, one would expect about 2.175 incidents of this kind per year if they were of the same magnitude as in the USA.

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4 The numbers are based on notices from 30 newspapers, police reports of incidents from 16 police departments and statistics from insurance companies. The following incidents are not included: Random snipers (so-called "thrill shootings") and objects thrown from overpasses. It does not include people injured or killed by armed robberies of motorists or other common highway crimes, or people injured or killed in "ordinary" drunk driving or hit-and-run collisions.
Concluding remarks

One of the major problems concerning aggressive driving behaviour, and the possible association with accidents in traffic, is to define in a clear way, what ‘aggressive driving behaviour’ actually is. This difficulty may be a reflection of the variation in definitions of aggression proposed by experts in this field. It is hence difficult to give advice to the police on what types of traffic behaviour they should address in their enforcement efforts. European drivers do, however, admit that they engage in close following, tailgating and chasing of other drivers.

Considering the literature on aggressive behaviour in traffic, it seems to be major differences between the USA and European countries concerning aggression in traffic. Judged from the reports, the ‘European problem’ with aggressive driving behaviour, seems to concern less severe levels of aggression and violence than the incidents recorded by Mizell and the AAA Foundation for Traffic Safety. ‘The American problem’ is a problem of violence and criminal acts taking place in the road system, not aggressive traffic behaviour as such. On the other hand, Europe and European countries have no known data collection system that records aggression, i.e. acts of violence, taking place in road traffic. Based on available reports presented and discussed here, comparisons between Europe and the USA are difficult, but there is little doubt that the problem of violence on American roads are of a much larger and serious scale than on European roads.

References


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5 If the incidents were of the same magnitude in Norway as in the USA, one would expect 5.8 incidents x 4.3 millions ≈ 25 incidents per year. This is not the situation in Norway. Judging from newspapers, 5 incidents took place during the years 1997 – 1999. Three of these involved taxi drivers against pedestrian or other road user.


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Mortality rates of motorcyclists compared with car occupants - A comparison between East and West Germany for 1980 - 1998

Introduction
The fall of the Wall in Berlin on November 9th, 1989 was one of the most impressive events in recent history. The subsequent reunification of East and West Germany led to manifold political, economical and social changes. Also, substantial alterations have occurred in traffic developments, and one of the most relevant parameters has been of special interest: traffic related mortality. Its development in East Germany was described in 1999 in the British Medical Journal as a "tragic consequence of the reunification of Germany" (6). Reported in this article was a sudden four-fold increase in mortality for car occupants between 1989 and 1991 from 4/100 000 to 16/100 000 residents. Although this increase was seen in all age groups, young adults were most affected with an eight-fold increase among those between 21 to 24 years of age and, indeed, an 11-fold increase in the ages of 18 to 20. Factors leading to these findings were, among others, deficits in driving experience, especially in these age groups, as well as a marked increase in traffic density and the acquisition of vehicles not previously available with advanced automotive technological standards (6).

As a research group with special interest in motorcyclist mortality, we conducted a comparative analysis of mortality among car and motorcycle operators for East and West Germany. In order for the comparison to take into account the 'normal' previous situations in both regions in Germany, the scope of the investigation encompassed the period both before and after reunification.

Material and methods
For the period 1980 - 1998, the following official statistics from the German Federal Office of Statistics [Statistisches Bundesamt] were retrospectively evaluated (4):

a) the number of registered cars and motorcycles (annually to the 1st of July)
b) general traffic mortality rates (as needed, with population data)
c) the annual mortality rates of motorcyclists and occupants of cars.

Recording of the data was separated for each region (East and West Germany). Following the governmental reunification all vehicles in the former GDR (German Democratic Republic) had to undergo re-licensing, that is they had to be registered and receive a new license plate according to West German licensing regulations. Because of this, the statistical material of the Federal Office of Statistics does not include information for the number of vehicles of East Germany for the years 1991 to 1993. To fill this gap, additional sources of information were used (Federal Motor Vehicle Office [Kraftfahrt-Bundesamt], State Office of Statistics [Statistisches Landesamt] of Berlin).

Based on these data (3) it was possible to calculate the number of cars and motorcycles, registered in East German for the years 1992 and 1993. It can be assumed that these data are sufficiently reliable. However, for the year 1991 information was not available at all and the number of registered cars and motorcycles is not included in any of the following figures. Also, beginning with the year 1998, the Federal Office of Statistics regrettably no longer differentiated their numbers for the parameters relevant here (as a summary for each East and West Germany). Again, a re-calculation for 1998 was necessary for the corresponding parameters and also resulted in sufficiently reliable assessments.

The reporting of the data and their graphical presentation was made using MS Excel and MS PowerPoint 2000.

**Results**

The development of the absolute number of motorcycles and cars is shown in Figure 1: With regard to cars, a for the most part continuous increase of about 50% can be seen in the observation period between 1980 and 1998, culminating in about 34.5 Mio, while there was a nearly four-fold increase in motorcycles to 2.7 Mio, with a discernable boom in the number of motorcycles in the early 80s and 90s.

An entirely different picture was seen in the number of cars and motorcycles in the former GDR/East Germany (Figure 2): Up to the time of reunification the number of
cars increased by about 50% to 3.9 Mio in 1989, with a further near doubling to approximately 7.2 Mio in 1998. For motorcycles the development was totally contrasting. After a fairly constant number of about 1.3 Mio motorcycles, the number fell drastically to about one-sixteenth of that number to about 0.08 Mio, before increasing in 1998 to about nearly 0.3 Mio motorcycles.
The differences in motor vehicle registrations is particularly pronounced when the absolute number of motorcycle registrations is presented in a percentage relationship to the number of cars (Figure 3): In West Germany, one can see the over proportional growth in the number of motorcycles with a relatively constant increase from 3% to in

1998 not quite 8% of the number of cars. In contrast, the proportion of motorcycles in East Germany with regard to the total number of cars was nearly 50% at the beginning of the period investigated, and then sank to 34% before reunification. In 1992, the proportion dramatically fell further to only 2%, then rising to slightly less than 4% by 1998.

If the number of motor vehicles is compared to the total population, the comparison between East and West Germany is shown in Figure 4 as the relationship between the two regions (the columns [logarithmic ordinates] present the number of motor vehicles in the former GDR/East Germany, each on the basis of a percentage relationship to West Germany; an equal motor vehicle density in the same year would correspond to a value of "100%"). While, up to reunification, the number of cars in the former GDR shows a small increase from 42% to 49%, after reunification, there is a sharp increase to
91% in 1998, thus nearly reaching the level in the West (100% would represent completely reaching the level in West Germany). With regard to the number of motorcycles, again the complete opposite development can be seen: The number of motorcycles compared to population at the beginning of the observation period was 650%, in other words 6.5 times higher than that for West Germany. Up to reunification, the number decreased, but was at the time of reunification still 3.6 times higher than in West Germany (364%). Afterwards, in 1992 it was only a fifth (21%), subsequently rising to the end to 45% (thus, nearly one-half of the West-German level).

The development of the general traffic mortality in both regions is shown in Figure 5. In West Germany there was a clear decreasing trend from 212 to 84 deaths per 1 Mio residents, resulting in a factor of 2.5. In the former GDR traffic mortality started at 120 deaths per 1 Mio residents: a clearly lower factor of about the half and up to reunification, a slight drop was noted. Then in 1991, there was an enormous increase to more than double, with a maximum of 236 deaths per 1 Mio residents and despite the subsequent decrease to 142 deaths per 1 Mio residents in 1998, the level of still approximately 70% higher than in West Germany.
Figure 6 shows the development of fatalities among motorcyclists and Figure 7 shows fatalities among car occupants in West Germany, each per 100 000 vehicles and as absolute number.

With regard to motorcycles there was a decrease by a factor of 6 from 167 to 26 per 100 000 vehicles in the observation period, among car occupants there was a steady decrease from 28 to 10 per 100 000 vehicles (factor 3).
The corresponding conditions in the other part of Germany are shown in Figures 8 and 9. Up to reunification there was a slight decrease in mortality among motorcyclists (Figure 8) in the former GDR from 26 to 18 per 100 000 vehicles. After reunification in East Germany there was a steep, initially 8-fold increase to 174 deaths per 100 000 motorcycles. This fell greatly to (in 1998) 61 deaths per 100 000 motorcycles.
With regard to car occupants (Figure 9), there was a slight decrease in fatalities in the former GDR up to reunification from 18 to 15 per 100 000 vehicles. Starting then in East Germany there was a dramatic increase by a factor of 4 to a maximum of 54 deaths per 100 000 vehicles in 1992. Up to 1998, a decrease was seen to 20 deaths per 100 000 cars, which was double that of West Germany.

In Figure 10, the direct relationship of deaths between motorcyclists and car occupants in both regions are compared with one another. At the beginning of the observation period, the mortality rates among motorcyclists in West Germany was about six times higher than that among car occupants. Starting at the mid-eighties, a slow continuous decrease was witnessed to "only" 2.7 times as many at the end of the observation period. In contrast, up to reunification in the former GDR the mortality rates among motorcyclists was only a maximum of double that of car occupants; in 1989, the rates were practical identical (1.1 times as many deaths among motorcyclists compared to car occupants). Following reunification in East Germany, a sharp increase was noted in traffic fatalities among motorcyclists; up to 1998, the rate was nearly constantly about 3 times higher than that of traffic fatalities among car occupants; at the end of the observation period, fatalities among motorcyclists was 3.1 times higher than by car occupants.
Using the same methodology as in Figure 4 (the number of motorcycle and car registrations), Figure 11 presents a direct comparison of traffic mortality for motorcyclists and car occupants per 100 000 motor vehicles in the former GDR/East Germany on the basis of the number in West Germany (= 100% in each year): in the case of identical mortality in the eastern region, the result for that year would be "100%". One can see that for car occupants, the number of traffic fatalities was well under the level for West
Germany before reunification: In 1980, the percentage was 64% of that in West Germany (about one-third less). Starting in 1989, traffic fatalities in East Germany was slightly higher than the rate in West Germany (105%). Following this, there was a sharp increase so that in 1992, the proportion of traffic fatalities among car occupants was over four times that in West Germany (406%). The rate started to decrease after 1992, but finally in 1998 it was still double that of West Germany (203%). At the start of the observation period in 1980, mortality rates among motorcyclists was six times lower in the former GDR compared to West Germany (only 16% in 1980), despite the higher number of motorcycles (see above). Up to reunification, a doubling was noted to 33%. The period from 1989 to 1992 witnessed an initial 11-fold increase to 365%; from 1992 to the end of the period under investigation, this mortality showed a decrease, but it was still 2.3 times higher in the East compared to the West and deaths among motorcyclists was still somewhat higher than among car occupants (234% versus 203%).

Discussion
The comparison of the general traffic-related mortality as well as the specifically motorcyclists' and car occupants' mortality has revealed considerable differences between both parts of Germany in the study period 1980 to 1988. Moreover, the numbers for the former GDR (German Democratic Republic) / East Germany showed substantial differences before and after the reunification: at first it was clearly below the level in the West, subsequently there was an enormous increase as the "tragic consequence of the reunification". The most relevant factors explaining those differences can be found within the following triangle:
**Factor vehicle:** As demonstrated above, reunification lead to fundamental changes in numbers of vehicles. The underlying reasons can only be understood if the specific special situation of the former GDR are taken into consideration. Mainly due to the peculiarities of this industrial society conditions the acquisition of cars was (in comparison to the West) much more difficult, e.g., because of long waiting times. This resulted, on one hand to a comparatively lower number of cars and traffic density, and on the other hand to a wider distribution of motorcycles as the commonly used motor vehicle before reunification, compared to the more frequent role of a recreational vehicle in West Germany. After reunification in East Germany, the number of motorcycles initially fell rapidly, because there was a larger need to "catch up" in the acquisition of cars. Through the immediate availability there was a sudden massive acquisition of newer Western technology, which on one hand led to a fast increase in the number of cars as well as a practically complete exchange of obsolete East German low technological standard.

**Factor motor vehicle operator:** Following reunification the driver as active participant in vehicle traffic was confronted with a completely new situation in East Germany: there was a large increase in traffic density along with the need to master a new motor vehicle technology. Sufficient driving experience was the primary prerequisite to overcome this new situation. Subsequently, it came as no surprise that for the most part young people, with only minimal driving experience, were the most affected by the enormous increase in traffic mortality. The easily identifiable and rapid flattening of the peaks of traffic deaths in the period immediately following this can be seen as an indication for relatively fast successful adaptation to the new traffic conditions. What also greatly contributed to the flattening of the peaks was basic and refresher driver training and continuous driver education. Further to be mentioned are the efforts on the part of the police to conduct control measures, particularly alcohol and speed control (5). Focussing on motorcyclists and their excessive rates of traffic fatalities compared to car occupants: this was certainly lower before reunification. Afterwards, the absolute number of deaths fell considerably, but although the number of motorcycles dropped significantly, the excessive mortality rate with regard to those related to this type of
vehicle rose enormously. Considering the characteristics of this type of vehicle, driver experience plays a larger role than with car drivers (single track vehicle, little in the way of safety equipment such as passenger compartment, seat belt, airbag). Especially for motorcyclists, proactive support is a possible alternative, for example in the form of repeated safety training.

**Factor traffic infrastructure:** The dramatic increase in mobility and the number of motor vehicles as well as the altered behaviour of motorists was compounded by an inadequate traffic infrastructure. The aged road network in East Germany was from a period in which the basis of modern road construction for highly technologically developed motor vehicles and their speeds was not known. The renovation and reconstruction of the road network was imperative considering the changed traffic conditions. This safety deficit was addressed in the form of a road network restructuring, through safety-relevant measures such as re-paving highways, the installation of safety barriers on the dividing strip, safety posts and renovation measures such as longer merge lanes for entering and exiting highways and new methods of markings on the highway system. In the framework of this special traffic safety program and through improvements in driving practices, including speed limits, sites of frequent accidents were made less critical (1,2,5). Because of the above mentioned motorcycle characteristics, motorcyclists are particularly endangered by an unfavorable road network infrastructure.

In general, the sudden push in motorisation with unfamiliarly powerful motor vehicles in a poor road network infrastructure and high proportion of inexperienced drivers led to a sharp increase in traffic deaths in East Germany. This development was a part of the rapid societal changes that were connected to the integration of the former GDR to the West German societal and economic systems. (2) Finally, according to the authors of the British Medical Journal paper mentioned at the beginning, a most relevant consequence which is primarily of interest for nations in a developing modernisation process has to be pointed out. For West Germany, reunification seems to have had little effect on car travel and death rates: a continuation of its decreasing development of traffic mortality was still seen after reunification. The people there had had access to world
markets long before reunification, so the opening of the borders did not increase the access to inexperienced drivers of vehicles, especially vehicles with an advanced technological standard. Contrary to this, the situation in East Germany was marked by sudden economic changes resulting in availability of vehicles, that in turn resulted both a rise in vehicle ownership and an increase in the number of inexperienced drivers on roads that were ill prepared for the increased traffic. Although such rapid changes are unlikely to occur elsewhere, knowledge gained from the period of German reunification could save lives in nations where economic development is proceeding more gradually and where large shifts in the characteristics of road users are occurring. The lesson that can be learned from German’s reunification is that during times of social and economic changes and modernisation, measures to prevent the predictable injury and deaths that will result need to be considered. Public health and the medical community especially in developing countries need to take the lead in ensuring that economic change does not adversely affect the health and safety of the public (6).

References


POLITICS, VIOLENCE AND ROAD SAFETY
Why are South African roads such dangerous places?

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INTRODUCTION
This paper attempts to examine the reasons behind the behavior on the roads of South Africa today which has led us to a death rate of some 15 x that of developed countries such as Australia, the United States and Europe. I am fully aware that we have a lower rate of crashes than many developing countries in the world which account for 70% of global deaths, although they only carry 30% of the traffic. South Africa is a society in transition, with a history markedly different from most developing countries, with its own special circumstances and conditions.

The paper is a reflection on the political and social history of my country, and an entirely personal view of the factors which I perceive to be contributory to the carnage on our roads, and the attitudes and behavior which contributes to that carnage. I am aware that I am speaking to engineers, scientists and other people who base their work on logical and scientific principles, and my presentation will concentrate on behavior, emotion, personal perception and some social analysis. Please bear with me on our journey.

THE ROOTS OF APARTHEID
The old South African government embarked on a social engineering program which became known world-wide as Apartheid, and which was denounced by the United Nations as "a crime against humanity". This policy built on the inequalities which were rampant under 200 years of Dutch and British colonisation, and which, among other hardships, deprived more than 80% of the population of rights to most of their land as early as 1913. At the Rivonia Trial where ex-President Nelson Mandela was the first accused, he gave a clear summary of past atrocities: "Already (by the early 1960s) scores of Africans had died as a result of racial friction. In 1920 when the famous leader, Masabala, was held in Port Elizabeth, twenty four of a group of Africans who had gathered to demand his release were killed by the police and White civilians. In 1921 more than one hundred Africans died in the Bulhoek affair. In 1924 over two hundred Africans were killed when the Administrator of South-West Africa led a force against a group which had rebelled against the imposition of a dog tax. On 1 May 1950 eighteen Africans died as a result of police shootings during a strike. On 21 March 1960, sixty-nine unarmed Africans died at Sharpeville"

By the time that the Nationalist government came into power in 1948, black resistance had already begun, and over the next nearly five decades, suppression of black political ambitions and boosting of political and economic status of whites as well as maintenance of their privilege was the prime objective of state structures including security forces.

As resistance movements attempted to organise in an endeavor to retain and then gain some political voice, the state became more and more heavy-handed in resisting change towards a more democratic and equitable society. For nearly half a century the majority of people in South Africa had no political,
economic or social voice that was heard by government or the international community, and resistance to the fight for freedom and equality by state forces was heavy, violent and continual.

The Truth and Reconciliation Commission was set up in 1996 to establish as complete a picture as possible of the causes, nature and extent of gross violations of human rights which were committed during the period 1960 to 1994. The primary finding of the Truth and Reconciliation Commission states “The predominant portion of gross violations of human rights was committed by the former state through its security and law-enforcement agencies. Moreover, the South African state in the period from the late 1970s to early 1990s became involved in activities of a criminal nature when, amongst other things, it knowingly planned, undertook, condoned and covered up the commission of unlawful acts, including the extra-judicial killings of political opponents and others, inside and outside South Africa.”

INSTITUTIONALISED VIOLENCE

This institutionalised violence is one of the factors which has led to the legacy of violence which exists in our society today. There was no respect from the State for human life and property. In a well ordered society the family is the main structure around which civil society, education systems, the churches, government agencies and the security forces form concentric circles of responsibility and authority. In a “normal” society, if a family collapses, then the education system or social security acts to assist the victims, and to re-establish their position in society. If this does not operate, then the next level of authority should support the individual or community who is not managing.
In South Africa, the ultimate authority, the Government, used their security forces to move through these levels of authority and attack individuals, families and entire communities in their homes. Legislation such as the pass laws and influx control forced families to live apart, and caused traditional community and extended family support to weaken. The education system for blacks was designed to discourage academic advancement, and to produce a subservient population who would fulfill roles as obedient labourers.

All of these moves were resisted by the African majority, who found it difficult to mobilise because of violent state suppression and lack of infrastructure in their communities. In 1990 only 2% of people in black communities had access to telephones. Televisions were only introduced in 1975 in South Africa, and even then there was little world coverage, heavy censorship, and limited coverage in mother-tongue. The policy of dis-information and control of media by the state kept people isolated from other communities, from the political struggle, and from world trends.

Many black leaders went into exile to further their educations and the struggle against oppression, and vast numbers of their followers left the country to be trained as soldiers to take up the call to armed conflict when it was made. Many of the leaders who remained within the country went underground to continue the struggle, or were arrested, detained or killed, either judicially or extra-judicially. South Africa for many years had the highest rate of capital punishment in the Western world. Many of the people hanged were killed for political crimes, when social crimes often went unpunished because of security resources being used by the regime to maintain the system of apartheid, colloquially referred to as "separate development".
TRANSITION, UNEMPLOYMENT AND POVERTY

In the early 1990s when tens of thousands of militarily trained exiles started to return to South Africa, the international economic recession led to a situation where many were unable to find work. Some of these men were able to survive and to fill the material expectations of their families through resorting to crime.

All of these factors, the increasing suppression, the economic impoverishment, the breakdown of family life, the call to the people to make themselves ungovernable, and the proliferation of both legal and illegal arms, has led to a situation where many South Africans are armed - and dangerous. The economic situation, political frustrations and heavy state suppression with army and police concentrating on protecting "white" interests led to a very high level of crime in black society. Now that we are in a new dispensation, and security is more equitable, levels of crime in areas which were previously advantaged have increased markedly. The perception of a general increase in violence and crime is incorrect, but crime has moved from being mainly in the disadvantaged communities to being more general in all sectors of society.

The result of this social engineering has meant that South Africa is one of the most violent societies in the developed world. Our murder rate is among the highest in the world, and is only superceded by countries such as Columbia. One is 70 times more likely to be murdered in South Africa than in England, and more than 40 times more likely than in even the most violent parts of the United States. About 600 Police in South Africa die at the hands of criminals each year, and the police kill many more than that, although there is now no legitimate death penalty in terms of the new constitution. More people are dying now at the hands of police and security forces than were killed by those forces in the early and mid-1990s.

EDUCATION AND BEHAVIOR IN COMMUNITIES AND ON THE ROADS

In a speech during 1998, Mr Cyril Ramaphosa stated that damage done to South African society through the lack of adequate education has had the greatest long-term effect on our society because it incapacitates generations of people. One of the first acts of the Nationalist government elected in 1948 was to stop subsidies for black schools. Education for White children was compulsory and largely free. The SA Institute for Race Relations in its 1963 journal, stated that approximately 40% of African children in the age group 7 - 14 years did not attend school. The Government spent R144.57 on each White child per year, and less than 10% of that amount (R12.46) on African children. Schools are still violent places. Children and teachers are sometimes armed, and recently there have been two incidents where massacres have occurred on school premises when teachers have argued in staff rooms.

In KwaZulu Natal 15,000 people were killed in political violence alone (state orchestrated, "low-intensity", black on black conflict) between 1984 and 1994. Levels of family murders, muggings, rape, high-jackings, security robberies, suicides and other violent crime are extremely high in comparison with both first world and developing nations.

In this society of violence and intolerance, it would be extremely surprising if our roads were safe places, where people were polite and tolerant and had a respect for human life. To expect "normal" behavior in any area of our still "abnormal" society is unrealistic.

South Africa is also a very authoritarian and paternalistic society, where the image of a man is to be strong, militant and "macho". It is a society which for years legislated a mans "rights" over his women and family, and which, to a large extent, still prescribes to this ethos, in spite of the protection of one of the most progressive constitutions in the world. This leads to aggressive behavior, which is reflected in driving conduct, a passion for fast cars, and even rampant road rage. South African society has for many years accepted abuse of alcohol as the "norm" even to the extent of it being an extenuating circumstance for crimes committed. One driver in seven on our roads in the evening is over the legal alcohol limit, and
most crashes occur in the evening hours and over weekends. The same “macho” ethos leads to widespread abuse of women and children in our society.

ENGINEERING

From a structural/road-engineering point of view, the rural areas of South Africa and the “townships” and informal settlements have remained largely undeveloped. There is a wonderful network of arterial roads and highways, sometimes four or five lanes wide, which criss-cross the land. These connect towns and cities, and lead in and out of previously disadvantaged areas and were developed partially to make the fast and safe movement of troops and military equipment possible during times of political “unrest”. In KwaZulu Natal there is even a section of the N3 near Estcourt which was designed to be suitable for the landing of military aircraft.

There has been insufficient infrastructure created for the safe road use by pedestrians in most areas, and too little government subsidy of travel for the poor, or facilities for taxis to enable them to pick up and drop off passengers safely. The taxi industry is not regulated, causing problems with control which leads to poor vehicle design, condition and maintenance and illegal licenses of both drivers and vehicles. Because many of our informal settlements have not been planned, often schools are on one side of a main road, and homes on the other. Sometimes shack settlements have grown up illegally and are established actually within the road reserves. Taverns and shebeens are informal businesses, which are not planned to enable safe travel home for patrons, often in inebriated states. 70% of adult pedestrians killed on our roads are drunk. This means that nearly 3000 lives are lost each year nationally because of drunken road use by pedestrians, and 1000 children die when they are hit by vehicles.

ACCESS TO JUSTICE

The South African judicial system cannot cope with the level of prosecutions in terms of either crime or road traffic offences. In some jurisdictions only 3% of murders are followed by successful prosecutions and convictions. The Administrative Adjudication of Road Traffic Offences Act (AARTO) was designed to bring about a change in the “culture of impunity” on the roads which presently exists. It has been passed by parliament and is due to be implemented in late 1999. This will involve not only collection of fines, but demerit points which can lead to suspensions of licenses, and confiscation of property for non-payment of traffic fines, as well as introduce a standard policy nationally regarding punishments. This will remove the majority of road offences from the courts and enable the judicial system to once again be a tool in combating social crime.

Nearly 10,000 people die annually on the roads, and many times that number are permanently disabled or seriously injured. This is seventeen times the “world’s best practice”, and can certainly be changed, with skillful public relations campaigns which will limit the resistance of sections of the community which sees heavy enforcement as a continuance of the suppression and over-regulation of the past.
Dealing with society on many levels will change road behavior. Concentration on speed reduction, backed up by a comprehensive advertising campaign clearly indicating the emotive consequences of unsafe behavior, will have the most immediate effect because most road crashes could be avoided or the degree of damage lessened if they occur at lower speeds. Comprehensive alcohol programs - high levels of enforcement synergised by mass media - will change attitudes to drinking and driving. In the medium term improved road infrastructure (low cost engineering projects at black spot sites) will ensure that pedestrians have less chance of being involved in conflicts with vehicles. Education programs in schools and communities will have a long term effect, and enable us to maintain the downward spiral. Overall, the state and security forces having a respect for human life will eventually change attitudes and encourage our society to become gentler and more responsible.

International experience has proved that, with the political will and sufficient allocation of resources to enable the implementation of a scientifically based, data driven, road safety program which integrates enforcement, advertising, public awareness, education and engineering elements as well as strong community participation, we should be able to achieve a 50% reduction in road deaths over the next five years. This will reduce the present rate of nearly 20 deaths per 10,000 vehicles to 10 deaths per 10,000 vehicles, and will save R20 billion and 15,000 lives nationally over the five year period. Between 1996 and 1999 the Asiphephe Road Safety Programme in Kwa Zulu Natal alone has saved approximately 2000 lives and R1.2 billion, as well as untold suffering. The cost benefits of a program of this nature are enormous. The saving of pain of unnecessary deaths, permanent injuries and serious damage is immeasurable, especially in a society which has suffered so much violence over the past half century, and which looses so many of its people by having one of the highest incidences of HIV/AIDS in the world.
CONCLUSION

To again quote from Mr Mandela’s Rivonia Trial defence in April, 1964 "Our fight is against real, not imaginary, hardships. Basically we fight against two features which are the hallmarks of African life in South Africa and which are entrenched by legislation which we seek to have repealed. These features are poverty and lack of human dignity”. Thirty five years after this historic speech, it is possible that these two root features are still basic elements in the high death rate on our roads. The lack of self-esteem caused by generations of oppression, the image conscious response to a history of poverty which leads to a "macho" approach to driving in the most at-risk groups, and the spawning and perpetuation of an unregulated taxi industry which has contributed to thousands of deaths. The majority of South Africans are still victims of the system, still living in poverty, still relying on an unregulated public transport industry, and living far out of cities and away from their places of work.

South African road safety experts do not see this as a mission impossible. They see Road Safety as a necessary element in the change of our society, to heal the scars of the past, saving both lives and money. If we re-engage a respect for human life on our roads, this philosophy will spill into other areas of society, leading to a reduction of crime and violence in communities and homes throughout South Africa and ensuring the survival of our fragile and new democracy.

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Eye movement recording as a tool for accident in-depth investigations – a pilot study.

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Abstract
In order to increase traffic safety for unprotected road users in Sweden, a project based on accident in-depth investigations was carried through. The project focused on accidents between unprotected road users and motor vehicles. The accident in-depth investigations studied the pre crash phase. As part of the investigations, eye movement recordings and analyses were done in order to identify possible “mechanical filters”, i.e. a certain obstacle or hindrance for adequate visual information to reach the driver in a particular road accident site.

The aim of this pilot study was to investigate whether or not eye movement analyses can be useful as a tool for a better understanding of the accident causation and, furthermore, for identification of possible “mechanical filters” in the traffic environment.

The results from this pilot study showed that in 75 % of the investigated accidents, in which eye movement recording were part of the investigation, the eye movement analyses played a major role or a conclusive role. Furthermore, the outcome from the investigated accidents were recommendations for a reconstruction of the accident site, partly based on the findings from the eye movement analyses.

It was suggested that an investment in an eye tracker and in employing medically educated professionals may be a good investment, if it can lead to a decrease in traffic accidents and, hence, a decrease of fatalities and severe injuries from road traffic accidents, by pointing out “mechanical filters” leading to accidents.

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**Introduction**

The human visual system and the driver
The human visual system consists of two sub-systems, foveal and peripheral vision. Foveal vision is restricted to a visual angle of approximately 1° around a fixation point. It provides the driver with high-resolution information, which supports capabilities such as recognition (Samuelsson and Nilsson 1996). Peripheral vision enables the driver to detect changes in contrast and movement, but with decreased visual acuity. Peripheral vision supports capabilities such as the driver’s orientation, but without the driver being fully conscious of this process (Leibowitz 1986). These two systems operate simultaneously and are dependent on each other. When driving, the driver uses his foveal vision to detect directional cues, while the peripheral system is used to maintain lateral control of the vehicle (Rockwell 1972). Peripheral vision also provides the driver with a wide range of visual information from which the foveal sampling of features takes place.

Visual search strategies in theory
The visual sampling is based on cognitive processes (Yarbus 1967). The sampling process is dependent on eye movements. Eye movements are directed by an individual schema of the driver (Neisser 1967), which is updated with information gathered by both peripheral and foveal sampling. The goal of this information gathering is to identify certain features in the traffic environment in order to control the vehicle, as shown in Figure 1.

![Figure 1: A model of driver information processing, adopted from Lansdown (1996)](image-url)
In the “Prioritisation of cues” process, “Experience” is one of four inputs. An integral component of “Experience” is the schema of the driver.

The visual system and its’ relation to traffic
An indisputable fact is the importance of the visual system as an input channel for information necessary when driving (Spijkers 1992). The extent of this input channel, in comparison with other input channels, has, however, been debated (Sivak 1996). The visual system has been investigated in relation to accident involvement also for novice drivers and drivers with some experience (Groeger, Kuiken et al. 1990). It was found that there was a moderate relation between the observation task, i.e. the use of the visual scanning system, and accident involvement, and it was concluded that visual search strategies were a major area of concern. Visual search strategies can be detected by measuring eye movements.

Eye movement recording
A driver’s eye movements can be measured using an eye movement recorder. There are several such apparatus on the market. A commonly used method to detect the eye movements is the infra red light cornea reflex technique. NAC EMR 600 represents a recorder using this technique. It is a head mounted eye tracker equipped with an NTSC video recorder for data storage. The video based data are analysed using the NAC Data Processing Unit linked to a PC in order to establish fixation data. The fixation generation procedure is discussed in a paper by Falkmer and Gregersen (2000) and is cited below.

Fixations; theoretical framework, definition and analysis
“The driver identifies certain features (i.e. cues) in the traffic environment by fixating. In daily life, the fixation point is assumed to reflect the focus of attention. There is, however, laboratory evidence that a foveal fixation point does not necessarily represent visual attention (Posner 1980; Groner 1988). A change in focus of visual attention is possible without a change in point of fixation, although it is not possible to change the fixation point without changing the focus of visual attention (Shepherd, Findlay et al. 1986).

The fixation point can be extrapolated from eye movement data. Eye movement data from dynamic scenes, such as driving, require special criteria to be used for determination of fixations, due to the fact that virtually all objects perceived by the visual system are in motion (Chapman and Underwood 1998). Fixations are generally defined as mean x,y co-ordinates of the fixation points, yielding an area of \( a \cdot a \) °, lasting a minimum of \( t \) ms (Chapman and Underwood 1998; Maltz and Shinar 1999). The reason for this definition is that fixations need to be separated from saccades, due to the fact that during the saccade a person is virtually blind (Yarbus 1967). Hence, a fixation can be defined as the period between two saccades, i.e. the inter-saccadic interval (Hooge and Erkelens 1997). The criteria for a fixation are set so that eye movements with an average speed higher than a certain value, i.e. saccades, can be excluded from the fixation point analysis.

Almost no fixations are shorter than 100 ms (Cohen 1977). Hence, the sampling rate of the eye movement data is crucial for setting the criteria. An insufficiency high sampling rate, i.e. <10 Hz, makes the t-value of 100 ms unusable. With a sampling rate of 30 Hz, a t-value of 100 ms means that at least three consecutive video frames must contain fixation points located within an area of \( a \cdot a \) °. The a-value criterion is dependent on the resolution of the eye movement recorder and the prerequisites of the experiment. Crundall and Underwood (1998) used 2.2°, Maltz and Shinar (1999) used 1.1° and Chapman and Underwood (1998) 0.25-0.25°.
The fixation has a location and a duration value. The mean duration is dependent on the interactions among prior fixations, the amplitude of eye movements, the characteristics of the object fixated, and the present schema of the subject, as well as information processing time (Cohen 1977). In general, fixation durations provide a measure of the information content of the fixation as well as the information processing strategy used by the subject (Chapman and Underwood 1998). The typical fixation duration is about 360 ms with SD 220 ms and a skewness of 2.18 (Cohen 1977).

The location of the fixation can be analysed both quantitatively, (e.g. Chapman & Underwood, 1998; Crundall & Underwood, 1998; Mourant & Rockwell, 1970; Mourant & Rockwell, 1972), and qualitatively (e.g. Spijkers, 1992). The quantitative approach provides information about where in the visual field fixations are located and for how long. The qualitative approach provides information on what (objects) fixations are directed. The drawback of the qualitative approach is, as stated previously, that it only provides indicative information about the focus of attention. The quantitative approach, in turn, although providing fixation point data, still generates an interpretation problem, i.e. what in the surrounding environment does a fixation point represent?

Eye movement recording as a tool for accident in-depth investigations

The visual processing is mainly done unconsciously and, hence, hard to describe retrospectively in detail by the driver. In fact, it is almost impossible to orally present a complete description of how a traffic scene was perceived. A commonly used expression in accident in-depth investigations is “looked but failed to see”. The reasons for “failed to see” are, however, seldom evident for the driver himself/herself. For this reason the use of eye movement recording and fixation analyses may contribute to understand why a driver did not “see” a certain object within the traffic scene, by providing data on fixation points.

There may be several reasons for “not seeing”. One way to classify them is to introduce the concept of filters. The first filter that an object within the traffic scene has to pass is a “mechanical filter”, i.e. a certain obstacle or hindrance for the visual information to reach the driver. The second filter is a “perceptual filter”, i.e. limitations of the drivers capacity to obtain information from the traffic scene. The third filter is a “cognitive filter”, i.e. lack of knowledge, experiences or incorrect anticipation on the traffic scene.

Background to the present pilot study

The risk for a fatal outcome of a traffic accident in Sweden is comparatively low. In addition, there has been a decreasing trend over the past 20 years in the number of fatalities related to traffic accidents both in relative and absolute figures. However, for bicyclists the reverse pattern has occurred. For bicyclists the relative risk for fatality in case of an accident is five times higher than for drivers of private cars. For pedestrians the corresponding figure is 11 times higher. (SNRA official statistics).

In order to increase traffic safety for unprotected road users in Sweden, a project using accident in-depth investigations was carried through (Ahlcrona et al. 1994). The project focused on accidents between unprotected road users and motor vehicles, under a 12 month period in the southern most area in Sweden.

A “case study” methodology, based on an “on the spot”-approach, was used. The accident in-depth investigations focused on the “pre crash” phase. A specially designed team, comprising
vehicle inspectors, road construction technicians and a social scientist was organised. As part of the investigation of the “pre crash” phase, eye movement recordings and analyses were carried out on a test driver, in order to identify “mechanical filters” in the traffic environment. However, not all accidents were chosen for eye movement recording. Only those accidents, in which a suspicion was raised about existing hindrance for relevant visual information to reach the driver, were subjected to eye movement recording and analyses. The decision was taken by the specially designed team. In this project 50% of the accidents were investigated using eye movement analyses.

Aim of the pilot study
The aim of this pilot study was to investigate whether or not eye movement analyses can be useful as a tool for a better understanding of the accident causation and, furthermore, to identify possible “mechanical filters” in the traffic environment.

Methods
Eye movements were recorded with an NAC 600 eye movement recorder (Kielgast, 1994). The equipment uses a cornea reflex system to measure the movement of the eyeball in the horizontal and vertical directions.

By using infra red light reflected on the cornea, movements of the eyeball are registered with an accuracy of ±0.17° and a frequency of 30 Hz. Synchronous with the registration of eye movements, the surroundings ahead are recorded with a video camera mounted on the headset. The apparatus is shown in Figure 2.

The co-ordinates representing the direction of gaze are linked to the video recordings. The resulting video film tape shows the surroundings from the perspective of the subject.

Figure 2  The NAC 600 eye movement recorder mounted on a test person’s head.
Data analysis in the present pilot study:
In the present pilot study, the qualitative approach was adopted. The analyses of the eye movements were focusing on the “mechanical filter”.

The $t$-value in the study was set at 100 ms. Furthermore, a minimum $a$-value of $1.1^\circ$ was used, based on the fact that foveal vision is restricted to a visual angle of approximately $1^\circ$ around a fixation point. Hence, the Data Processing Unit was set to recognise fixations where at least three consecutive data samples, measured at 30 Hz, fell within a minimum of $1.1^\circ$ of each other, using a centroid procedure. This gave a minimum fixation duration of 100 ms and allowed pursuit tracking to be classified as a fixation.

The video based data were analysed frame by frame for those sets of frames clustered into a fixation. The fixation durations were noted.

The test driver drove a pre-defined route of 10-20 minutes including the accident spot. The test driver was unaware of the actual accident spot and the pre-defined route were driven at least three times, in order to control for learning effects. The test driver were asked to comment his driving, while driving, in order to enhance identification of possible “mechanical filters”.

The analyses of the eye movements were made using a semi-blind approach. The responsible researcher knew the actual accident spot and, hence, which frames to be analysed. The characteristics of the accidents were, however, unknown to him. For this reason, the analyses were not biased by any pre assumptions on what could have been a “mechanical filter”. The eye movement analyses were then sent in to the specially designed team and were added to their investigations. In addition, the eye movement analyses were classified by the specially designed team with respect to their contribution to the accident in-depth investigations. The classifications were done using the following parameters: “The eye movement analysis played:

- no role at all for the accident in depth investigation, or
- a minor role for the accident in depth investigation, or
- a major role for the accident in depth investigation, or
- a conclusive role for the accident in depth investigation”

Results
In total, eight traffic accidents were analysed using eye movement recording. Of these accidents, three had a fatal outcome. In three accidents the unprotected road user sustained severe injuries and in two accidents the unprotected road user got only slightly injured. The specially designed investigation team classified the eye movement analyses with respect to their contribution to the accident in-depth investigations. The results are presented in Figure 3.
Eye movement analyses and their contributing role to the investigations.

Figure 3: The role of the eye movement analyses with respect to their contribution to the accident in-depth investigations, n=8.

The eye movement analyses were just one part of the accident in-depth investigation. Together with technical inspections of the traffic environment and the vehicle, and interviews with the persons involved or witnesses, the cause of the accident was established. In addition, suggestions for improvement of the traffic safety were given. In all eight accident in-depth investigations, referred to above, i.e. in which eye movement analyses were performed, suggestions for improvement of the traffic environment were suggested. The results are presented in Table 1.
Table 1: A summary of the investigated accidents types, causes and suggestion for improvements.

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Vehicles involved</th>
<th>Time of day</th>
<th>Road condition</th>
<th>Accident outcome</th>
<th>Cause of the accident</th>
<th>Suggestion for improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>Private car - bicycle</td>
<td>Night</td>
<td>Wet</td>
<td>Fatal</td>
<td>“Mechanical filters”, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Other</td>
<td>Private car - pedestrian</td>
<td>Day</td>
<td>Dry</td>
<td>Severe injuries</td>
<td>“Mechanical filters”, Vehicle malfunction, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Other</td>
<td>Private car - pedestrian</td>
<td>Night</td>
<td>Wet</td>
<td>Fatal</td>
<td>“Mechanical filters”, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Intersection</td>
<td>Private car - bicycle</td>
<td>Day</td>
<td>Dry</td>
<td>Severe injuries</td>
<td>“Mechanical filters”, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Intersection</td>
<td>City bus - bicycle</td>
<td>Day</td>
<td>Dry</td>
<td>Severe injuries</td>
<td>“Mechanical filters”, Vehicle malfunction, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Intersection</td>
<td>Private car - bicycle</td>
<td>Day</td>
<td>Dry</td>
<td>Mild injuries</td>
<td>“Mechanical filters”, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
<tr>
<td>Intersection</td>
<td>Private car - bicycle</td>
<td>Day</td>
<td>Wet</td>
<td>Fatal</td>
<td>“Mechanical filters”, Human error</td>
<td>Reconstruction of the accident site.</td>
</tr>
</tbody>
</table>

**Discussion**

Road traffic accidents, leading to fatalities or severe health losses constitute a major public health problem. Approximately 650,000 persons are killed annually by the road transport system. Even in countries with a relatively high level of traffic safety, still 5% of the population are either killed or permanently disabled due to road accidents. The cost for the society is, with no doubt, high, not to mention the ethical aspects of this issue, and even a small reduction of the number of road traffic accidents could lead to a substantial cut down of these costs.

1 In this column individual improvements of human performance and adjustments of vehicle malfunctions are not mentioned, due to the fact that all these interventions were on an individual level and, hence, no generalisations could be made.
Accident in depth investigations could be a key to a better understanding of accident causes and, hence, guide traffic engineers and politicians towards creating a more user friendly traffic environment. The present pilot study has shown that by including eye movement analysis as an integral component of accident in-depth investigations, a higher quality can be reached, especially with respect to the traffic scene, i.e. to identify “mechanical filters”.

Performing eye movement recording and analysis of the gathered data, as a part of accident in-depth investigations requires, on the one hand economical means to buy and adapt an eye tracker and to hire medically educated professionals for the analysis. This may, however, be regarded as hard to realise in a decreasing or small economy. On the other hand, an investment in an eye tracker and medically educated professionals may be a good investment if it can lead to a decrease in traffic accidents and, hence, to a decrease of fatalities and severe injuries from road traffic accidents, by pointing out “mechanical filters” leading to accidents.

Acknowledgements
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Projected Highway Fatalities Involving Older Drivers in the United States, 2000-2020

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Abstract

The aging of the population is a phenomenon being experienced by all developed countries around the world. Although the population in the developing world is younger, it too is aging. This phenomenon subjects our society to many social and economic challenges, one of which is the balance between mobility and safety of aging drivers. In order to better position our society to address this challenge, it is essential to develop a better understanding of the size of the highway safety problem involving future elderly cohorts. This paper presents a series of models that project total highway fatalities that involve future older drivers, from the year 2000 to 2020. The projections take into account changes in driving behavior, personal wealth, infrastructure, and technological impacts. The projections were based on three major premises:

- the probability that an elderly driver will continue to drive varies by gender, age, and other driver attributes;
- the amount of driving by an elderly driver varies by gender, age, and other driver attributes; and
- the likelihood of involving in, and dying from, a highway crash also varies by gender, age and other driver attributes.

Based on recent trends, it was found that an older driver's decision to continue to drive decreases with being female, living in an urban community, being unemployed, having lower income, having other drivers in the household, being functionally disable, and being older. If continue to drive, drivers drive more miles if they are young, employed, male, have higher income, and do not have other drivers in the household.
STEPPING STONES TO A SAFER COMMUNITY: REFLECTIONS OF THE SANTA SAFE COMMUNITY EXPERIENCE.

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SUMMARY

This paper looks at the process facilitated by the CSIR and the Northern Cape Department of Transport, in the community of Santa, Kimberley in the Northern Cape Province.

The Safe Communities project is aimed at creating safer environments and behaviours in order to reduce and minimize the impact of injury on health, development and the well-being of the people in Santa.

The main characteristics of the Safe Communities approach are:
- expanded partnerships,
- community involvement and input,
- data analysis and where possible data linkage, and
- an integrated and comprehensive injury control system.

Therefore, the main objective is to develop and promote a model for an integrated and comprehensive injury control system that can be used in the community by the community members themselves. Communities are in the best position to affect improvements in safety related problems. When a community takes ownership of an issue, change happens.

The CSIR, through their experience, have embraced the following framework for facilitating community-driven safety:
*Empowerment of people by enhancing their personal capacity and self-worth so that they can become aware of their potential to meet their needs through participation and ownership of the process of development.*

This paper also looks at the various participatory educational technologies (PET), developed by the CSIR, in the framework of a safe community-driven process, within the Santa pilot project. The participation and ownership of road safety issues within communities is presently an important vehicle of change in South Africa.

These techniques embraces a range of approaches, methods and behaviours that enable people to express and analyse the realities of their lives and conditions in terms of road safety, to plan themselves what action needs to be taken to address these road safety issues, and then to monitor and evaluate the results. The techniques can facilitate the process of community members learning about road safety in their community through the various techniques.
such as mapping, modelling, matrix ranking, flow diagrams, venn diagrams and many other techniques.

In the paper, the process and technologies are presented and discussed as they were implemented in the community of Santa.
TRAFFIC SAFETY ON THREE CONTINENTS

TOPIC: A SELF-HELP TRAFFIC SAFETY PROGRAMME FOR SCHOOLS

ABSTRACT

The aim of the project is to change learner attitudes towards Road Safety issues in their communities, by means of a participatory project. For learners to endorse the Department of Transport project, “Arrive Alive”, they need to know why road safety is so important. They also need to understand the consequences we all face from those who do not abide by road safety practices. The best way to provide that information is through encouraging communities to be involved in identifying their own road safety problems and be involved in researching their solutions.

Public education must do more than just informing, it must create an environment for change. It must change the learners’ attitude and it must provide a hands-on opportunity for learners to solve road safety problems on their own. This is true since it has been proved in most community work that, when a community takes ownership of an issue change happens.

Everyone can play role in this process, from community road safety forums/councils, Traffic Law Enforcement officers, SAPS, Education institutions, information centers and Private Sector. The participation and ownership of road safety issues within communities, is presently an important vehicle of change in South Africa. The CSIR’s Traffic Management Programme has been actively involved in community development. They have been instrumental in the establishment of community-based road safety forums/councils, thereby gaining a lot of experience in facilitating community ownership and participation.

The CSIR through their experience have embraced the following framework for facilitating community-driven road safety: “Empower people by enhancing their personal capacity and self-worth so they can become aware of their potential to meet their needs through participation and ownership of their process of development.”

The project is aimed at encouraging learners to take ownership and be responsible for road safety problems in their communities. Experts must transfer relevant skills in the following areas:

→ How to plan and execute research;
→ How to identify problems in a community approach;
→ How to find or develop solutions in a participatory approach;
→ How to implement the identified solutions.

The Road Safety Education Directorates should serve as a basis/vehicle of change in the Provinces’ Department of Education’s regions. The objectives of the project are therefore:

→ To encourage learners to be aware of road safety issues/problems;
→ To teach learners to take responsibility of road safety issues that affects their communities.
→ To empower learners, educators and road safety officials and other relevant role players to participate in practical experimental work on road safety problems;
→ To develop and enhance the learners presentation skills by means of a practical presentation session during an evaluation camp;
→ To promote teamwork and participatory learning by means of Participatory Educational Techniques (PET).

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The evaluation of a precocious preventive action of alcohol and drugs consumption in Brittany

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The Ancestor Barnabon is a play designed to make children aware of the dangers of the excessive consumption of alcohol or drugs together with aggression or speed when driving.

As a continuation to the stage-play, a pedagogical booklet, designed in collaboration with the educational authorities in the area, refers back to the characters and themes and is given to the teacher to help him to pursue the work inspired by the play.

By April 1998, 4000 children aged from 7 to 11 had already seen the show. This was therefore a large-scale operation.

The Barnabon project - show and pedagogical follow-up booklet was a success. It had sufficient impact for children to reconsider their reactions, with a better comprehension of the risks involved. We could assume that with this improved knowledge they would better understand the risks involved even if adolescent psychology may produce a certain disappointment in this respect.

This greater awareness of risk is applicable to all the different areas dealt with by this awareness activity; it is seen to be relatively homogenous but slightly more noticeable with regard to Tobacco, Drugs and Healthy lifestyles. It is less noticeable for Road dangers. Prevention measures regarding tobacco, drugs and a lifestyle detrimental to health would appear to be particularly effective, as significantly fewer children remained undecided or refused to answer.

Our survey showed that the most important aspect of the show and the booklet was in helping to help promote dialogue and open up discussion: using the enjoyment of a stage-play for prevention purposes.

In the near future, we would also consider extending this to a neighbouring area that has not yet been covered: some of the classes in this area could form a control group.
Session 5  Road Safety Problems and Solutions in Africa, Europe and The US

A comparative study of road safety between the USA, UK and South Africa
C.J. Mollet

Road safety problems of developing and developed countries
B. K Yanney

Comparing road fatalities in three continents
C J Bester

Towards establishing a reliable accident data system in Ghana
Shaibu Bawa

Road safety education curriculum for South African schools
Tiese de Coning

Lithuania road traffic safety programme for 2000-2005
Alvydas Pikūnas

Road safety policies in seven west African countries
Nicole Muhlrad
A COMPARATIVE STUDY OF ROAD SAFETY BETWEEN THE USA, UK AND SOUTH AFRICA

By CJ Mollett Pr Eng

CHIEF ENGINEER : TRAFFIC ENGINEERING
PROVINCIAL ADMINISTRATION OF THE WESTERN CAPE

ABSTRACT

The object of this study is to compare the trends and levels of road safety between the USA, the UK and the RSA after 1966. These countries will be compared on the basis of their respective levels of personal safety, transport safety and mobility/motorization. To make meaningful comparisons these indicators will be compared at equal levels of mobility and transport safety. It will be shown that South Africa has the worst levels of personal and transport safety. It will also be shown that although the USA has a similar level of transport safety as the UK, its level of personal safety is considerably worse than that of the UK at similar levels of mobility.

1. INTRODUCTION

The objective of this paper is to make a comparison of road safety in the United States of America (USA), the United Kingdom (UK) and the Republic of South Africa (RSA) after 1966.

There are at least two ways to describe the safety level in a country- by means of personal safety and transport safety. The indicators used as a measure of personal safety and transport safety are called the temporal accident rate and the spatial accident rate respectively (Wilde – 1994). These two indicators have completely different meanings and cannot be used interchangeably. Each one of these indicators on its own does not and cannot reveal the full picture regarding the state of road safety in a country. However a clearer picture is revealed when both indicators are considered together and how they interrelate with each other.

When interpreting these indicators it is important to consider that the task of driving is a productive activity. According to Glahe and Lee (3) a productive activity is any activity that increases utility. A road user is a consumer. He/she consumes the mobility offered by the road transportation system to gain utility. Furthermore a road user is a rational consumer, in other words, he/she will always attempt to maximise his/her’s utility, subject to his/her’s budget constraints.

It is also important to keep in mind that both the UK and the USA are highly developed countries. According to the Human Development Report of the United Nations Development Programme (1998) the USA has a Human Development Index of 0.992 (rank = 4) and the UK an Index of 0.986 (Rank = 14). South Africa is still a developing country with a Human Development Index of 0.717 (Rank = 89).
2. DATA

The analyses and comparisons made in this paper are based on the data contained in the Appendix. Reliable information on total kilometres travelled in South Africa is not readily available, therefore when South Africa is compared to the UK and the USA only vehicle based rates will be used.

It is important to note the differences in the definitions of what constitutes a road traffic accident fatality in these three countries. In South Africa a fatality is defined as when a person dies as a result of an accident within 7 days after the accident. This period in the UK is 30 days and in the USA it is 1 year. The analyses will be based on the actual number of fatalities recorded in each country (according to their own definitions), with no adjustments made.

3. TEMPORAL ACCIDENT RATE

An accident rate expressed as accidents (e.g. fatalities) per population is referred to as a temporal accident rate.

The temporal accident rate indicates the risk to any member of the population of being involved/injured/killed in a traffic accident. It is also referred to as a measure of personal safety. Temporal accident rates reflect the extent to which road accidents constitute a public health problem, compared with, for example, HIV/AIDS or tuberculosis.

According to Wilde (8) the annual accident loss in a country is the consequence of the hourly risk (R) people are willing to take, multiplied by the time (h) they spend on the road, multiplied by the number of people in the population (P).

\[
A = R \times h \times P
\]

\[...[1]\]

\(R\) in the above expression can also be referred to as the ‘target level’ of risk. Target risk, according to Wilde (8), can be defined as the level of subjective risk that road users are willing to accept when using the road transportation system. It is that level of risk where the perceived cost is equal to the perceived benefit.

Equation 1 can be rewritten as follows:

\[
\frac{A}{P} = R \times h
\]

\[...[2]\]

Equation 2 shows that the temporal accident rate for a country, for a specified period of time, is equal to the total risk the citizens of a country are willing to accept when using the road transportation system. In economic
terms the temporal rate is equivalent to a person’s budget for the acquisition of mobility.

According to Wilde (8) the target level of risk, and therefore also the temporal rate, is a function of the following 4 subjective utility factors:

1. The expected benefits of risky behaviour e.g. gaining time by speeding (+)
2. The expected cost of safe behaviour e.g. peer pressure (+)
3. The cost of risky behaviour e.g. motor vehicle repair costs (-)
4. The expected benefits of safe behaviour e.g. insurance discounts (-)

The higher the levels of utility factors 1 and 2, the higher the level of target risk, and the higher the levels of utility factors 3 and 4, the lower the level of target risk.

Graph 1 shows the temporal accident rates for the UK, USA and South Africa expressed in terms of the number of fatalities per 100,000 of the population.

According to Wilde (8) an important factor to consider when analysing temporal rates is the prevailing economic conditions in a country. When the economy is in recession, for example, the expected benefits associated with ‘risky’ behaviour are reduced (i.e. utility factor 1 decrease), because time is worth less money. There is less to be gained from driving a lot of kilometres and from driving fast. At the same time the expected cost of risky behaviour e.g. fuel cost, maintenance etc. increases relative to real income. The result is a reduction in the target level of risk and hence a decrease in the temporal accident rate.
In a study of American trends in the annual number of traffic fatalities between 1960 and 1983 Partyka (7) used three variables that produced a remarkably accurate prediction. These variables were; the annual number of people employed, the annual number of people unemployed and the number of people not in the labour force. These variables produced good results because they are obviously related to the size of the population as well as to the economic situation in the country.

Another measure of the economic situation in a country is the unemployment rate. Wilde (1994) found the following product-moment correlation coefficients between annual unemployment rates and temporal rates for the USA and the UK: USA (1948 – 1987) = -0.68 and UK (1960 – 1985) = -0.88.

2.1 CONCLUSIONS

a) Of the three countries South Africa appears to have the highest temporal rate. The average South African road user is therefor willing to accept a much higher level of risk when using the road transportation system than his/her’s American and British counterpart. In turn the level of target risk in the USA is higher than in the UK.

b) To maximise the utility they derive from their transport system the South African nation as a whole is willing to ‘tolerate’ more fatalities per capita then the UK and the USA. Similarly the USA is willing to ‘tolerate’ more fatalities per capita than the UK.

c) The chances of a USA citizen being killed in a road traffic accident are considerably larger than that of a UK citizen, but not as high as in South Africa.

d) Road accidents are a bigger social health problem in the USA than in the UK.

3. SPATIAL ACCIDENT RATE

An accident rate expressed as accidents per kilometre travelled is referred to as a spatial rate. Often because of the unavailability of information on total kilometres travelled in a year, the spatial rate is expressed as the number of accidents per registered vehicle. The number of registered vehicles is information that is routinely available.

The spatial accident rate is a measure of transportation safety i.e. it indicates the risk associated with using the road transportation system. The spatial rate indicates the extent to which accidents constitute a traffic problem. In economic terms the spatial rate is equivalent to the unit cost or price of mobility.

The trends of the vehicle based spatial accident rate (fatalities per 10 000 registered vehicles) for the USA, the UK and the RSA are shown in Graph 2.
It is evident that there has been a consistent exponential reduction in the rates for the USA and the UK since 1966. The rates for other developed countries like West Germany, the Netherlands, Canada etc. also follow a similar pattern (Wilde and Oppe). The rates for RSA do not follow the same pattern.

Adams (in Haight - 4) refers to these exponential curves as ‘national learning curves’. These curves show how a country has learned to cope as the threat of traffic has grown.

A country could adapt in many ways. Individuals might learn how to be safer road users, the safety of motor vehicles may improve, the government may build safer roads, legislation may be passed to govern certain aspects of driver behaviours e.g. seat-belt wearing etc. It is to be expected that the rate of adaptation or successes achieved will vary between different countries. This process of adaptation must be affected by the national culture and identity. It involves may disciplines including the engineering, medical, law enforcement and scientific disciplines. The cumulative result of the efforts by all these disciplines has been an exponential decline in accident rates.

Graph 2 : Vehicle based spatial rates for the UK, the USA and the RSA

To determine the rate of decrease in the spatial rates for the UK and the USA, models with the following form have been fitted to the data from both countries :

$$\log(R_Y) = \alpha + \beta Y$$

Where
Rs - Either the vehicle based or distance based spatial rate.
Y - Year - 1966

Table 1: Regression results

<table>
<thead>
<tr>
<th>Rs</th>
<th>Country</th>
<th>α</th>
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There are periods (of short duration) where the spatial rate actually increased. According to Haight (4) the increase in the rate for the USA between 1975 and 1980 correspond to a period of increased economic activity. From Graph 1 it is evident that there has been a substantial increase in the temporal rate over this time. In other words the level of target risk increased and to compensate for this increase drivers behaved in a more risky manner e.g. driving faster etc. Improved economic conditions could lead to an increase in alcohol consumption and more employment opportunities (and thus more mobility) for the youth – the road user group associated with the highest accident risk.

3.1 CONCLUSIONS

a) Relative to the UK and the USA it is unsafe to use South African roads.

b) Since about 1985 road transport has been safer in the UK than in the USA.

c) It appears as if the safety of the South African road transportation system, and to an extent the behaviour of road users, has been very sensitive to the social, economic and political changes and events in the
transport industry, the socio-economic and political situation in the
country. Events like the fuel crises, sanctions, the deregulation of the
road freight industry, the proliferation of minibus taxis, to name but a
few, possibly all contributed to the pattern of transport safety in South
Africa.

The quality of the physical road infrastructure in South Africa is probably
comparable to that of the USA and the UK. The reason then why the
South African spatial rates are so much higher relates primarily to the
large percentage of pedestrian fatalities. This is a consequence of a
large part of the population that cannot afford motorised transport –
hence South Africa’s relatively low motorization rates. During 1998 38.1
% of all fatalities were pedestrians. The majority of pedestrians killed are
from previously disadvantaged groups. High rates of speeding, the non-
wearing of seatbelts, unroadworthy vehicles and high drunk driving
rates, especially in the presence of perceived non-existent traffic law
enforcement and an ineffective judicial system, all contribute to the high
spatial rate.

d) Since 1966 the distance based spatial rate in the UK has decreased by
5.6 % per year compared with the 3.8 % of the USA. Based on Adams’
learning curve theory it appears that the UK, at least since 1966, has
been more successful in coping with the threat of accidents than the
USA.

4. MOBILITY / MOTORISATION

Mobility can be defined as the average number of kilometres travelled per
person of the population in a specified period of time. Motorization on the
other hand can be defined as the average number of vehicles per person of
the population. In economic terms the level of mobility/motorization is
equivalent to the demand per capita for the use of the road transportation
system.

\[
\text{Mobility} = \frac{\text{Temporal rate}}{\text{Spatial Rate}}
\]

From Graphs 4 and 5 it is evident that there has been a consistent increase
in the level of mobility/motorization in all three countries and that in the USA
and the UK the mobility has an inverse relationship with the spatial rate.

Wilde (1988) provides the following explanation. As the road transportation
system becomes safer the spatial rate decrease. In order to maintain their
target level of risk drivers compensate for the decrease in the risk of
travelling by either driving increased distances and/or driving in a more risky
manner e.g. at increased speeds. If drivers do not make this adjustment
they will operate at a level below their target level of risk, which means that
they do not behave like rational consumers.
The irregularity in the curve for the USA at about 1974 was caused by a sudden reduction in vehicle ownership levels during the 1973 -1974 oil crises.

To compare the exponential growth in mobility between the USA and the UK after 1966 a regression model with the following form was applied to the mobility data for both countries:

$$\log(M) = \alpha + \beta Y$$

Where
\( M \) - Mobility (kilometres/population)
\( Y \) - Year - 1966

Table 2: Regression results

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<tr>
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<th>( \beta )</th>
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<th>se(\beta)</th>
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It can be shown that the \( \beta \)-coefficients of the two models are significantly different from each other.

4.1 CONCLUSIONS

a) The USA since 1966 has experienced considerably higher levels of mobility than the UK and South Africa.

b) Since 1966 the UK has experienced a higher rate of growth than the USA – 2.9% versus 2.2% per year respectively.

5. COMPARING MOBILITY

Meaningful comparisons concerning the demand for a product can only be made if the product is available to all parties at the same price.

In order to make a comparison of the demand for mobility it is necessary to make such comparisons at similar spatial rates for the three countries concerned. Such a comparison is difficult in the sense that the UK and the USA have never since 1966 experienced the spatial rates South Africa experienced between 1970 and 1989, and South Africa has never since 1970 experience the levels of motorization that the UK and the USA experienced.

Graph 6: Motorization vs. Spatial Rates – RSA, UK and USA
It appears as if at low spatial rates the demand for mobility in South Africa could be less than for in the UK and the USA, while at higher spatial rates the demand for mobility could exceed that of the UK and the USA. Due to possibly large prediction errors and incorrect model choices Graph 6 should be interpreted with caution.

Graph 7 shows the demand curves for just the USA and the UK. Whereas Graph 6 was based on the demand for of motorization Graph 7 is based on the demand for mobility.

It is evident from Graph 7 above that the average demand for mobility in the USA is considerably higher than the UK.

6. COMPARING TEMPORAL RATES

Meaningful comparisons concerning the total budget for a product can only be made when the same amount of product is consumed by each party or when the product is available to all parties at the same price.

From Graph 8 it is evident that at similar levels of the spatial rate the USA have higher temporal rates than the UK and that the temporal rate in the USA has been more sensitive to changes in the spatial rate than in the UK. In turn a change in the temporal rate (as a result of changes in the target risk) has caused larger changes in the spatial rates in the UK than in the USA.
Graph 9 indicates the relationship between *mobility* and *temporal* rates for the UK and the USA.

It is evident that for similar levels of *mobility* the *temporal* rates in the USA have been considerably higher than in the UK. This implies that the USA is willing to ‘pay’ more in total for a certain level of *mobility* than the UK.
7. GENERAL DISCUSSION

It is evident that the reason why the level of personal safety in the USA is so much worse than that of the UK is the USA’s high level of target risk which is a function of the following utility factors:

- Benefit of risky behaviour
- Cost of safe behaviour
- Benefit of safe behaviour
- Cost of risky behaviour

It appears as if the high levels of target risk in the USA are manifested primarily as high mobility levels.

An increase in mobility constitutes ‘risky’ behaviour (increased exposure to risk) and a reduction in mobility constitutes ‘safe’ behaviour (decreased exposure to risk).

The benefits of risky behaviour i.e. high mobility levels probably relates to a desire to achieve economic growth and to sustain an economy which is widely considered as one of the best in the world. Furthermore high mobility levels can be associated with increased personal freedom and independence.

The cost of safe behaviour i.e. a reduction in mobility, could be reduced if there are acceptable alternatives, such as for example, a good, socially acceptable and an efficient public transport system. The USA has lower public transport ridership levels than other western countries as shown in Table 3. Furthermore, according to Cox (2), this level in the USA is decreasing by about 3 % per year.

Table 3 : National per capita urban transport ridership levels

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<th>Nation</th>
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<td>USA</td>
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Source: www.publicresponse.com/ut-natl.htm

The level of saturation i.e. the ratio of demand to supply, could impact on the cost of risky behaviour. Higher saturation levels are associated, amongst others, with congestion and air pollution. According to Oppe (6) in 1985 the USA already utilised 59 % of the maximum vehicle kilometres their transportation system could supply while the UK utilised 78 % of their supply. Could the perceived cost of ‘risky’ behaviour in the USA be lower than in the UK?

The road safety problem in South Africa has its roots in the high target level of risk of the average South African road user which appears to be manifested, not as increased levels of mobility, but as unacceptable human behaviour e.g. speeding, drinking and driving etc. In trying to find an
explanation for this, one cannot ignore South Africa’s *apartheid* history and the attitudes and perceptions that this fostered in the hearts and subconscious minds of its people.

8. **LIST OF REFERENCES**

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6. Oppe S; *Macroscopic models for traffic and traffic safety*; Accident analysis and Prevention; Volume 21, No. 3, pp 225 – 232; 1989


8. Wilde GLS; *Target Risk: Dealing with the danger of death, disease and damage in everyday decisions*; PDE Publications; Toronto; 1994


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ROAD SAFETY PROBLEMS OF DEVELOPING AND
DEVELOPED COUNTRIES

B.K. YANNEY
DEPARTMENT OF CIVIL ENGINEERING
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HARARE

ABSTRACT

The population of major cities in African and Latin American countries has more
than doubled over the last twenty years. The population growth has brought with
it a corresponding increase in vehicle ownership. Despite the increase in vehicle
ownership, developing countries have not embarked upon any meaningful and
sustainable transport management programs. In big cities of developing
countries, congestion created by illegal parking, hawkers, and street vendors
trying to make a living in the face of harsh economic reforms have all contributed
to transportation safety problems.

Accident rates in developing countries have been estimated to be 20 – 30 times
higher than those in European countries. The escalating vehicle accident rates
have created heavy drain on the economies of the developing countries which
continue to import transportation components using their scarce foreign
exchange reserves.

The need for effective transportation management backed by research cannot
therefore be over-emphasized. The paper discusses the accident rates for some
developed and developing countries and attempts to identify areas for research.
Accident fatality rates in developing countries have been compared with those in
developed countries.

1. INTRODUCTION

The term “traffic management” is usually used to describe the general process of adjusting
or adapting the use of existing road systems to improve traffic operation without resorting
to new major construction. Traffic management usually seeks to improve environment or
provide better access for people and goods. These aims can sometimes be in conflict with
each other and compromises may have to be made. However, most traffic management
schemes would seek to improve road safety as a by-product even if this was not the main
objective. The paper discusses accident fatality rates in selected developing countries and
attempts to compare the accident rates with those of developed countries.

Countries covered by this article are those in West Africa (viz. Sierra-Leone, Cote D’Ivoire,
Burkina Fasso, Niger and Nigeria) as well as others in East and Southern Africa (viz.
Ethiopia, Kenya, Malawi and Zimbabwe). Other countries in North Africa viz. Morocco and
Tunisia are also covered.
2. **SAFETY PROBLEMS IN SELECTED DEVELOPING COUNTRIES**

It is estimated (TRL 1991) that over 300 000 persons die and some 10 – 15 million persons are injured every single year in road accidents throughout the world. Fatality rates (with respect to vehicle numbers) in developing countries especially African countries can often be 20 – 30 times as high as those in European countries. Fig.1 shows the African countries covered in this article.

TRL (1978) has provided the fatality rates in developed countries in units of death/10 000 vehicles. Fig.2 gives similar figures (deaths/ 10 000 vehicles) as at 1978, while Fig.3 gives similar statistics for 1985/86.

3. **COMPARISON OF ACCIDENT FATALITY RATES**

Table 1 shows the data extracted from Fig.1 and Fig. 2. The data show that out of eleven randomly selected from the 1978 data, 95 deaths/10 000 vehicles were recorded as against 70 deaths/10 000 vehicles from 1985/86 results. This goes to show that accident rates fell from 95 to 70 deaths /10 000 vehicles between 1978 and 1985 mainly for developing countries. Within the same period the accident rates for developed countries fell from 3.5 to 2.7 deaths /10 000 vehicles.

Comparing the accident fatality rates between developing and developed countries it will be noted that there were 95 accidents in developing countries as against 3.5 in 1978 i.e. a ratio of 27:1 while in 1985 the accidents in developing and developed countries were respectively 70 and 2.7 i.e. a ratio of 26:1. This goes to prove that the accident fatality rates in developing countries are about 27 times higher than those in developed countries.

(a) **COMPARISON OF ACCIDENT FATALITY RATES IN DEVELOPING COUNTRIES**

Table 1 shows that as at 1978 (during the oil boom in Nigeria) Nigeria was leading all African countries in accident fatality rates by 235 deaths/10 000 vehicles. Hence the seven African countries with the highest accident fatality rates were Nigeria, Ethiopia, Malawi, Ghana, Kenya, Upper Volta, Niger and Togo. Between 1968-85 the accident fatality rates in Nigeria were nearly four times higher than those of Togo. Out of the 15 African countries selected Zimbabwe registered the least accident fatality rates of 25 deaths / 10 000 vehicles.
4. **CAR OWNERSHIP RATES IN SELECTED CITIES**

Table 2 gives the accident fatality rates for some selected cities.

**Table 2**

COMPARISON OF CAR OWNERSHIP RATES IN SELECTED CITIES

<table>
<thead>
<tr>
<th>CITY</th>
<th>CAR OWNERSHIP PER 1000 POPULATION</th>
<th>MEAN</th>
<th>RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABIDJAN</td>
<td>- 50</td>
<td>44</td>
<td>1:7</td>
</tr>
<tr>
<td>KARACHI</td>
<td>- 35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAGOS</td>
<td>- 47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEW YORK</td>
<td>- 220</td>
<td>290</td>
<td></td>
</tr>
<tr>
<td>LONDON</td>
<td>- 280</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARIS</td>
<td>- 370</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows that there are approximately seven times more cars in the industrialized cities than the cities of developing countries. Despite this fact it is curious to note that there are still over 20 times more fatality accidents in developing countries compared to developed countries.

5. **DECREASE / INCREASE IN ACCIDENT FATALITY RATES**

Fig. 4 shows the rates at which accident fatality rates have been decreasing / increasing between 1968 and 1985. Figures extracted from Fig.4 are given in Table 3 below.

**Table 3**

DECREASE / INCREASE IN ACCIDENT FATALITY RATES

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AFRICAN COUNTRIES</th>
<th>ASIAN COUNTRIES</th>
<th>DEVELOPED COUNTRIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1971</td>
<td>+75</td>
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<td>0</td>
</tr>
<tr>
<td>1978</td>
<td>+170</td>
<td>+60</td>
<td>-10</td>
</tr>
<tr>
<td>1980</td>
<td>+220</td>
<td>+110</td>
<td>-8</td>
</tr>
<tr>
<td>Mean</td>
<td>+155</td>
<td>+67</td>
<td>-6</td>
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</table>
Table 3 shows that the accident fatality rates are highest in African countries followed by Asian countries, and that, over the period, those accident fatality rates have increased by a mean value of 155% for African countries and 67% for Asian countries. While the accident fatality rates are increasing for African and Asian countries, the rates are decreasing for developed countries.

The following facts must be highlighted:
(i) Major cities in developed countries carry seven times more traffic than those cities in developing countries.
(ii) The accident fatality rates in developing countries are 20-30 times higher than those in developed countries, and finally
(iii) While the accident fatality rates in developed countries are decreasing, those in developing countries are increasing.

The facts on the increasing accident fatality rates in developing countries should create cause for concern. The situation needs to be controlled without delay.

6. **BREAKDOWN OF ACCIDENT FATALITY RATES**

Table 4 shows the breakdown of road accident fatalities with respect to causes. It will be noted from the results contained in Table 4 that accident fatalities fall into two main groups viz.
(i) Accident fatalities involving pedestrians and
(ii) Accident fatalities involving drivers and passengers.

The major countries leading in the two main groups are as follows:

(a) **ACCIDENT FATALITIES INVOLVING PEDESTRIANS**

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>84%</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>70%</td>
</tr>
<tr>
<td>Kuwait</td>
<td>55%</td>
</tr>
<tr>
<td>Swaziland</td>
<td>55%</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>51%</td>
</tr>
<tr>
<td>Jordan</td>
<td>47%</td>
</tr>
<tr>
<td>Kenya</td>
<td>45%</td>
</tr>
</tbody>
</table>
(b) ACCIDENT FATALITIES INVOLVING DRIVERS AND PASSENGERS

<table>
<thead>
<tr>
<th>Country</th>
<th>Fatality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jordan</td>
<td>50%</td>
</tr>
<tr>
<td>Zambia</td>
<td>49%</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>47%</td>
</tr>
<tr>
<td>Indonesia</td>
<td>44%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>44%</td>
</tr>
<tr>
<td>Nigeria</td>
<td>42%</td>
</tr>
<tr>
<td>Kenya</td>
<td>40%</td>
</tr>
</tbody>
</table>

By identifying areas where accident fatality rates are highest for each country, traffic management in those specific areas may be intensified. For example in Ethiopia 84% of accident fatality rates are related to pedestrians.

Therefore traffic management may be intensified in an effort to protect vulnerable road-users or to increase the effectiveness of high occupancy vehicles (HOV) by improving pedestrian areas. Where the traffic volume consists of a high content of cyclists then a decision can be made to provide cycle lanes. (See Table 6).

By carrying out recommended surveys (see Table 5) e.g. an inventory survey, the road characteristics, junction geometry and control, signal settings, street furniture and lighting, parking facilities and the safety of street vendors it may be possible to determine how the accident rates may be reduced.

In Zimbabwe, for instance, the report indicates that the greatest proportion of accidents involve drivers and passengers. There have been several cases of bus disasters in Zimbabwe. Attempts must be made to embark on accident data collection and analysis so that (if possible) highway design improvements at accident black spots can be implemented.

Effective mass transportation planning can also be implemented. In this case the recommended traffic surveys may be concentrated on road performance and driver behaviour, using manual recording, video surveys, or hand-held data capture devices. (See Table 5).

7. CONCLUSION
The paper serves to highlight the alarming accident fatality rates in African countries compared to Developed countries. Road accidents have been found to account for almost 2.5% of all deaths recorded in
some selected 19 third world countries. In fact, road accidents may be considered as the 10th most important cause of death. If consideration should be given to the fact that all types of vehicles are imported and paid for in foreign currency and that all the spare parts for the repair and maintenance of these vehicles are also imported then the road safety awareness campaigns deserve unreserved support.

8. **ACKNOWLEDGEMENTS**
The author is grateful to Transport Research Laboratory, Crowthorne UK for the generous supply of publications, some of which have been used in the preparation of this article.

9. **REFERENCES**


5. JACOBS, G.D. and I.A. SAYER “Road accidents in developing countries” Department of Environment, Department of Transport, Transport and Road Research Laboratory Crowthorne (1983).

### TABLE 1

**FATALITY RATES**

**VEHICLE ACCIDENTS (DEATHS/10 000)**

(a) **DEVELOPING COUNTRIES**

<table>
<thead>
<tr>
<th>Number</th>
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<th>DEATHS/ 10 000 VEHICLES</th>
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<td></td>
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<td>1978</td>
</tr>
<tr>
<td>1</td>
<td>NIGERIA</td>
<td>235</td>
</tr>
<tr>
<td>2</td>
<td>ETHIOPIA</td>
<td>210</td>
</tr>
<tr>
<td>3</td>
<td>MALAWI</td>
<td>170</td>
</tr>
<tr>
<td>4</td>
<td>GHANA</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>KENYA</td>
<td>70</td>
</tr>
<tr>
<td>6</td>
<td>UPPER VOLTA</td>
<td>70</td>
</tr>
<tr>
<td>7</td>
<td>NIGER</td>
<td>68</td>
</tr>
<tr>
<td>8</td>
<td>TOGO</td>
<td>64</td>
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<tr>
<td>9</td>
<td>CAMEROON</td>
<td>-</td>
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<td>10</td>
<td>LESOTHO</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>PAKISTAN</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>SIERRA LEONE</td>
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<td>13</td>
<td>COTE D’IVOIRE</td>
<td>40</td>
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<tr>
<td>14</td>
<td>CONGO</td>
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<td>15</td>
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<tr>
<td><strong>MEAN</strong></td>
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<td>95</td>
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(b) **DEVELOPED COUNTRIES**

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<tr>
<td>U.S.A</td>
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<td>2</td>
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<td>GREAT BRITAIN</td>
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<td>2</td>
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<tr>
<td><strong>MEAN</strong></td>
<td>3.5</td>
<td>2.7</td>
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**TABLE 4**

PERCENTAGE OF FATALITIES BY ROAD–USER CLASS

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>YEAR</th>
<th>Pedestrians</th>
<th>Cyclists</th>
<th>Motorcyclist &amp; Scooters</th>
<th>DRIVERS AND PASSENGERS</th>
<th>TOTAL</th>
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<td>19</td>
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<td>44</td>
<td>100</td>
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<td>5</td>
<td>17</td>
<td>37</td>
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<tr>
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<td>40</td>
<td>100</td>
</tr>
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<td>22</td>
<td>13</td>
<td>33</td>
<td>32</td>
<td>100</td>
</tr>
<tr>
<td>Zambia</td>
<td>1977</td>
<td>40</td>
<td>8</td>
<td>3</td>
<td>49</td>
<td>100</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>1979</td>
<td>36</td>
<td>9</td>
<td>2</td>
<td>47</td>
<td>100</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1980</td>
<td>32</td>
<td>5</td>
<td>19</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

**SOURCE:** Transport Research Laboratory
Crowthorne, Berkshire (U K)
<table>
<thead>
<tr>
<th>Information</th>
<th>Description</th>
<th>Survey methods</th>
</tr>
</thead>
</table>
| **Road use**                        | Traffic volumes on links and at junctions. Volume & density lane occupancy & effective width.  
   Peak/off-peak differences daily & seasonal variation.  
   Traffic composition  
   Pedestrians                           | Traffic counts by time of day (manual / automatic), junction turning movement studies, vehicle occupancy counts |
| **Service quality**                 | Road speeds  
   Delays  
   Queues                                    | Radar surveys, stopwatch methods, video surveys, floating car, chase car number plate survey, input/output surveys, path trace, internal-based queue length event-based queue length |
| **Inventory**                       | Road characteristics  
   Junction geometry + control  
   Signal settings  
   Street furniture  
   Lighting  
   Parking facilities  
   Street vendors                        | Observation with standard form checklists                                      |
| **Parking**                         | Duration-temporal and spatial                                               | Parking ‘beats’                                                                |
| **Road performance and driver behaviour** | PCU values, speed flow  
   Gap acceptance and headway  
   Saturation flows at junctions  
   Following distances & speeds, compliance to red turning circles and stopping distances. | Manual recording, video surveys, hand-held data capture devices, number plate surveys. |

**SOURCE:** Transport Research Laboratory  
Crowthorne, Berkshire (U K)
<table>
<thead>
<tr>
<th>Category</th>
<th>Objectives</th>
<th>Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPROVE CAPACITY</td>
<td>Make efficient use of fuel. Reduce time wastage. Promote and develop the</td>
<td>Road &amp; junction improvement on-street. Parking and trading restrictions. Traffic signal improvements one way &amp; tidal flow system roadmarking and signing improvements</td>
</tr>
<tr>
<td></td>
<td>urban economy.</td>
<td></td>
</tr>
<tr>
<td>Allocate priorities</td>
<td>Protect vulnerable road-users. Increase effectiveness of high occupancy</td>
<td>Pedestrian areas cycle lands Bus or HOV lanes Selective detection at signals, exemption from other regulation.</td>
</tr>
<tr>
<td></td>
<td>Vehicles (HOV)</td>
<td></td>
</tr>
<tr>
<td>RESTRAINT</td>
<td>Improve Public Amenity Protect Environment Improve road safety</td>
<td>Parking controls Physical restraint Cordon restrictions Area licensing Road pricing.</td>
</tr>
</tbody>
</table>
FIG. 2

FATALITY RATES IN SOME DEVELOPING COUNTRIES (1978)

SOURCE: OVERSEAS UNIT
TRANSPORT RESEARCH LABORATORY
CROUThORNE, BERKSHIRE UK (1983)
FIG. 4

SOURCE: "TOWARDS SAFER ROADS IN DEVELOPING COUNTRIES"
TRL et alia (1981)
ABSTRACT

It has been shown in the past that the road fatality rates of different countries are dependent on the total vehicle ownership of such counties. Recent research has revealed that the passenger car ownership is a better predictor of the fatality rate of a country. This is also the case for the different continents.

When comparing the fatality rates of three continents, it was found that there are other socio-economic factors, such as income, illiteracy and life expectancy that also contribute to the large differences between the developed countries of the northern hemisphere and the developing countries of Africa.

Accident and fatality rates can be expressed in terms of the population, or the vehicle or passenger car population or the road network of a country. In the paper the comparisons are made for all four of these rates and the differences are discussed.

The relationships between road safety and the different socio-economic variables as applicable to the countries of the three continents are also shown. Conclusions are made regarding the reasons for the differences in fatality rates.

INTRODUCTION

The accident or fatality rates of different countries, areas or types of infrastructure are often compared in an attempt to determine possible causes for high (or low) accident and fatality rates. Sometimes it is simply done to determine benchmarks for countries or areas with unacceptably high rates.

The purpose of this paper is to report on a study in which the fatality rates of the countries of the three continents, Europe, North America and Africa, were compared. This was done in terms of infrastructure, transportation and socio-economic variables that were available from international databases. The relationships between the fatality rates and other variables were also determined for the three continents. This was done by means of stepwise regression analyses.

In the paper the data collection is described, comparisons in fatality rates are made and relationships between rates and socio-economic data are developed and discussed.
DATA COLLECTION

Data for the countries of the three continents were retrieved from the latest publications of international organisations such as the International Road Federation (1997) and the United Nations (1997, 1998). These figures are applicable to three different years, a span of two years - from 1994, for accident and transportation data, to 1996 for some of the socio-economic inputs. It is believed that the errors resulting from the fact that the data were representative of different years are less than the errors inherent in the data collection process in many of the countries.

The variables collected are shown in Table 1. For each variable and each continent the minimum (min) and maximum (max) value are given. Data on road fatalities are available for 33 countries in Europe, 18 countries in Africa and five countries in North America.

Table 1: Variables collected

<table>
<thead>
<tr>
<th>Variable</th>
<th>Europe</th>
<th></th>
<th>Africa</th>
<th></th>
<th>North America</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Fatalities</td>
<td>24</td>
<td>9814</td>
<td>22</td>
<td>9935</td>
<td>283</td>
<td>40676</td>
</tr>
<tr>
<td>Vehicles (million)</td>
<td>0.14</td>
<td>42.84</td>
<td>0.004</td>
<td>5.45</td>
<td>0.14</td>
<td>198.8</td>
</tr>
<tr>
<td>Cars (million)</td>
<td>0.12</td>
<td>40.50</td>
<td>0.003</td>
<td>3.81</td>
<td>0.07</td>
<td>149.1</td>
</tr>
<tr>
<td>Population (million)</td>
<td>0.3</td>
<td>81.8</td>
<td>0.4</td>
<td>127.0</td>
<td>3.2</td>
<td>265.0</td>
</tr>
<tr>
<td>Paved road network (1000 km)</td>
<td>3.1</td>
<td>644.0</td>
<td>0.3</td>
<td>70.6</td>
<td>1.7</td>
<td>3736.8</td>
</tr>
<tr>
<td>HDI</td>
<td>0.612</td>
<td>0.946</td>
<td>0.229</td>
<td>0.737</td>
<td>0.530</td>
<td>0.960</td>
</tr>
<tr>
<td>Life expectancy</td>
<td>67.5</td>
<td>79.0</td>
<td>44.5</td>
<td>70.0</td>
<td>67.5</td>
<td>79.0</td>
</tr>
<tr>
<td>Adult illiteracy (%)</td>
<td>0.2</td>
<td>17.7</td>
<td>14.9</td>
<td>69.0</td>
<td>1.0</td>
<td>34.3</td>
</tr>
<tr>
<td>GDP per capita ($1000)</td>
<td>1.52</td>
<td>42.42</td>
<td>0.08</td>
<td>5.00</td>
<td>0.46</td>
<td>26.0</td>
</tr>
</tbody>
</table>

The Human Development Index (HDI) is a combined index (Ul Haq, 1995) made up of the income (GDP per capita), the level of education (adult illiteracy rate) and the life expectancy of the population of a country or region. The HDI is published regularly by the United Nations.

Apart from the problem of the availability of data, the accuracy thereof can also be questioned. For instance, some countries report more injury accidents than the number of people injured in these accidents. This was then also the main reason why the study concentrated on fatal accidents only and not on injury or damage only accidents. There is also a problem with definition. In certain countries the number of vehicles may include farming implements, trailers, military vehicles, etc; and in others it may not include these vehicles. The definition of a road is also not consistent and often differs between administrative jurisdictions – especially when it comes to lower order roads. This is the reason why the paved, rather than the total length of road is used in Table 1.

The variables collected were used to determine different rates of fatalities, road use and vehicle ownership. In the next section, these are compared for the three continents.
COMPARISONS

The actual values of the variables for the three continents (for the countries with available data) are compared in Table 2.

**Table 2: Comparison of collected data**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Europe</th>
<th>Africa</th>
<th>North America</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of countries</td>
<td>33</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td>Fatalities (Total)</td>
<td>69,900</td>
<td>35,700</td>
<td>49,900</td>
</tr>
<tr>
<td>Vehicles (million)</td>
<td>215.6</td>
<td>10.8</td>
<td>230.1</td>
</tr>
<tr>
<td>Cars (million)</td>
<td>188.5</td>
<td>7.7</td>
<td>172.1</td>
</tr>
<tr>
<td>Population (million)</td>
<td>568.7</td>
<td>354.9</td>
<td>392.3</td>
</tr>
<tr>
<td>Paved roads (1 000km)</td>
<td>3212</td>
<td>246</td>
<td>4196</td>
</tr>
<tr>
<td>HDI (Average)</td>
<td>0.867</td>
<td>0.465</td>
<td>0.919</td>
</tr>
<tr>
<td>Life expectancy (years)</td>
<td>74.7</td>
<td>55.7</td>
<td>76.0</td>
</tr>
<tr>
<td>Adult illiteracy (%)</td>
<td>2.1</td>
<td>37.4</td>
<td>4.2</td>
</tr>
<tr>
<td>GDP per capita ($1 000)</td>
<td>16.1</td>
<td>1.1</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Although the total number of road fatalities and the populations are of the same order, the road infrastructure and number of vehicles in Africa are much lower than in the other two continents. Also, the level of development, as shown by the HDI, life expectancy, adult illiteracy and income is substantially lower in Africa than in Europe and North America. In the majority of cases, the difference between the attributes of the latter two continents is insignificant.

To compare the road safety situation of the three continents, different fatality rates were calculated. These are reflected in Table 3 and are also shown in Figure 1.

**Table 3: Comparison of road fatality rates**

<table>
<thead>
<tr>
<th>Fatality Rate</th>
<th>Europe</th>
<th>Africa</th>
<th>North America</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per 100 000 vehicles</td>
<td>32.4</td>
<td>330.6</td>
<td>21.7</td>
</tr>
<tr>
<td>Per 100 000 cars</td>
<td>37.1</td>
<td>463.6</td>
<td>29.0</td>
</tr>
<tr>
<td>Per million people</td>
<td>122.9</td>
<td>100.6</td>
<td>127.2</td>
</tr>
<tr>
<td>Per 1000 km of paved road</td>
<td>21.8</td>
<td>145.1</td>
<td>11.9</td>
</tr>
</tbody>
</table>

Unfortunately the fatality rate in terms of vehicle kilometres travelled is available for a few countries only and could not be determined as being representative of the three continents.

From Table 3 it is clear that in terms of vehicles and infrastructure the fatality rate in Africa is much higher than in Europe and North America – in the order of seven to 16 times as high. For the same rates North America seems to be safer than Europe. However, when the fatality rate per capita is compared, the situation is reversed with Africa having the lowest rate, followed by Europe and North America. This rate is often considered indicative as an indication of the seriousness of the contribution of road fatalities to the overall death rate. From these rates it is clear that Europe and
North America have, in terms of their overall mortality rate, a greater problem from road fatalities than the countries of Africa. This is then probably one of the reasons why the former countries spend more resources on the elimination of this problem. In Africa, infant mortality and AIDS create much greater health problems and have a higher priority in the allocation of resources.

RELATIONSHIPS

As early as 1949 Smeed has shown that the fatality rate of a country can be related to the number of vehicles per capita or as it is also known, the rate of motorization. In a recent study (Bester, 2000) on international road fatality rates, it was found that passenger car ownership is a better explanatory variable of fatalities per 100 000 passenger cars than vehicle ownership as an explanatory variable of fatalities per 100 000 vehicles. This logarithmic relationship, as determined for all the countries with available road fatality data (93 countries), is shown in Figure 2.

The general form of the relationship can be described as follows:

\[ \frac{F}{C} = a(C/P)^b \]  \hspace{1cm} ..................................(1)

where

- \( \frac{F}{C} \) = Fatalities per 100 000 cars,
- \( C/P \) = Cars per 1 000 people, and
- \( a,b \) = constants.

From Equation 1 it can be shown that:

\[ \frac{F}{P} = \left(\frac{a}{1 \, \text{000}}\right)(C/P)^{b+1} \]  \hspace{1cm} ..................................(2)

where

- \( \frac{F}{P} \) = Fatalities per 100 000 people.

This means that if the relationship between fatalities per 100 000 cars and car ownership is determined, the relationship between fatalities per 100 000 people and car ownership is fixed.

The values of \( a \) and \( b \) as determined by means of regression analyses for the world (Figure 1) and the three relevant continents are given in Table 4.

**Table 4: Constants in logarithmic relationship.**

<table>
<thead>
<tr>
<th>Area</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>All countries (93)</td>
<td>4 517</td>
<td>-0.807</td>
</tr>
<tr>
<td>Europe</td>
<td>14 618</td>
<td>-1.027</td>
</tr>
<tr>
<td>Africa</td>
<td>1 889</td>
<td>-0.414</td>
</tr>
<tr>
<td>North America</td>
<td>6 409</td>
<td>-0.911</td>
</tr>
</tbody>
</table>

The relationships for the three continents are shown in Figures 3, 4 and 5 respectively.
Figure 1: FATALITY RATES

- Per 100,000 vehicles
- Per 100,000 cars
- Per million people
- Per 1,000 km of road

FIGURE 2: FATALITY RATE VS CAR OWNERSHIP (93 COUNTRIES)
From Equation 2 it can be seen that the nearer the value of b is to \(-1\), the less the influence of car ownership on fatalities per capita which tends to a constant value. This is clearly the case for Europe and to an extent, for North America. For Africa, on the other hand, there is an increase in the fatalities per capita with increased motorization. This means that the improvement in safety as a result of increased motorization (Equation 1) is more than cancelled by the rate of motorization. The latter is also from a very low base. The average car ownership in Africa is 21.7 cars per 1 000 of the population. This can be compared to the values of 332 and 439 cars per 1 000 of the population for Europe and North America respectively.

Another relationship that is clearly illustrated by the combined data for the three continents is the effect of the Human Development Index on the fatality rates. This is shown in Figure 6.

**EXPLAINING THE VARIATION IN FATALITY RATES**

In a recent study of international fatality rates (Bester, 2000) it was shown that the variation in these rates can best be explained by the following variables:

- Car ownership (C/P);
- Human Development Index (HDI); and
- Percentage of vehicles other than passenger cars (PV).

The following equation was determined by means of stepwise regression analysis:

\[
\ln \frac{F}{C} = 18.066 - 0.633 \ln \frac{C}{P} + 6.65 \ln \text{HDI} - 11.447 \text{HDI} + 0.0160 \text{PV} \quad \ldots \ldots \quad (3)
\]
From the previous section it is clear that car ownership alone has different effects on the fatality rates of the different continents. This difference is the greatest where a large difference in the HDI is found, e.g. between Europe and Africa. The inclusion of the HDI in explaining the variation in fatality rates is further justified when separate models are developed for Europe and Africa. There are not enough data points for a separate North American model. The model fitting results are shown in Tables 5 and 6 for Europe and Africa respectively.

Table 5: Model fitting results for Ln F/C (Europe)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Coefficient</th>
<th>Std. error</th>
<th>t-value</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>31.30</td>
<td>9.241</td>
<td>3.387</td>
<td>0.0021</td>
</tr>
<tr>
<td>Ln C/P</td>
<td>-0.447</td>
<td>0.1291</td>
<td>-3.462</td>
<td>0.0017</td>
</tr>
<tr>
<td>Ln HDI</td>
<td>17.77</td>
<td>7.626</td>
<td>2.330</td>
<td>0.0272</td>
</tr>
<tr>
<td>HDI</td>
<td>-26.20</td>
<td>9.455</td>
<td>-2.771</td>
<td>0.0098</td>
</tr>
<tr>
<td>PV</td>
<td>0.030</td>
<td>0.0075</td>
<td>4.026</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

R² = 0.876

Table 6: Model fitting results for Ln F/C (Africa)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Coefficient</th>
<th>Std. error</th>
<th>t-value</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>10.57</td>
<td>1.163</td>
<td>9.089</td>
<td>0.0000</td>
</tr>
<tr>
<td>Ln C/P</td>
<td>-0.9086</td>
<td>0.234</td>
<td>-3.878</td>
<td>0.0015</td>
</tr>
<tr>
<td>Ln HDI</td>
<td>2.291</td>
<td>0.828</td>
<td>2.766</td>
<td>0.0144</td>
</tr>
</tbody>
</table>

R² = 0.436
It is interesting that for the 33 countries in Europe the same variables as for the international model (Equation 3) were included by the stepwise regression analysis. The model for Africa also included the HDI, but the percentage of the variation that is explained (43.6%) is much lower than for Europe.

DISCUSSION

From a comparison of the fatality rates of the three continents it is clear that in terms of vehicles and infrastructure the fatality rate in Africa is much higher than in Europe and North America – in the order of seven to 16 times as high. For the same rates North America seems to be safer than Europe. However, when the fatality rate per capita is compared, the situation is reversed with Africa having the lowest rate, followed by Europe and North America.

As far as infrastructure and car ownership are concerned, the road fatality rate in Africa is much worse than in the other two continents. As an example it can be shown that the country with the highest car ownership in Africa (South Africa) would have been the third lowest in Europe. Also, the socio-economic data show that the development in Africa is at a much lower level than in Europe and North America. This is illustrated by the level of education, life expectancy and income as reflected in the Human Development Index.

The relationship between fatalities per car and car ownership is valid for all three of the continents. However, the slopes of the lines are different, with that of Africa again much lower than those of Europe and North America. The result is a positive relationship between fatalities per capita and car ownership for Africa, whereas the fatalities per capita in Europe and North America are constant and not affected by the car ownership.

REFERENCES


TOWARDS ESTABLISHING A RELIABLE ACCIDENT DATA SYSTEM IN GHANA

By

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ABSTRACT

The Building and Road Research Institute (BRRI) from the late 1960s to the mid 1980s pursued accident data collection only for routine research activities. This approach did not help very much in laying bare the scale of the road accident problem in Ghana.

However, following the inception of the Ghana Road Safety (GRSP) in 1987 as part of the Government’s Transportation Rehabilitation Programme, accident data collection and analysis was institutionalised to provide vital data-led support to accident remedial activities pursued by the National Road Safety Committee (NRSC) and the road agencies. That much has been achieved was due to the collaboration between the BRRI and the Overseas Unit of the Transport and Road Research Laboratory (TRL) through the British Overseas Aid under the Ghana Road Safety Project (GRSP). The collaboration ensured that vital support in the form of technical expertise, establishment of an Accident Analysis Unit and Staff training was provided at the BRRI.

This paper tries to present the modest achievements made by the Accident Analysis Unit since its creation, at local accident registration and analysis in order to identify main local problems and develop the necessary action programme. And also to emphasise the importance of transfer of Western Experience to developing countries to improve local safety work.
1.0 INTRODUCTION

1.1 Background

Without doubt effective and meaningful work at improving road safety is impossible without a reliable and accurate data base. This fact had been one of the main focuses of the Building and Road Research Institute (BRRI) which from the late 1960s to the mid 1980s had been engaged in data collection for research purposes. However, these research activities died out with the economic problems of the 1980s. During this period the only information available on the accident situation in Ghana was the summary statistics collated by the police for public information. These figures were generally unreliable because of erratic differences in subsequent releases and the fact that not all the regions responded effectively to requests for returns on accident reports.

This greatly affected any efforts geared at practical safety work to assess the scale of the problem and find remedies to improve the situation.

The inception of the Ghana Road Safety Project (GRSP) as part of the Transport Rehabilitation/Urban Transport Project by the Ghana Government in 1987 with support from the World Bank, was timely intervention. The most important component of the GRSP was the establishment of the new accident data collection, storage and analysis system for Ghana and the training of an accident analysis unit at the Building and Road Research Institute (BRRI). In this regard road safety activities was institutionalised to provide data-led support to accident remedial activities pursued by the National Road Safety Committee (NRSC) and other government agencies working in this field.
That the objective of the GRSP was fulfilled was greatly due to the immense technical support received from the British Overseas Aid through the Overseas Unit of the Transport Research Laboratory (TRL). The Aid ensured that a computer programme designed for use on microcomputers and specifically for accident analysis in developing countries was made available to Ghana at no cost.

2.0 THE NEW SYSTEM CREATED UNDER THE GHANA ROAD SAFETY PROJECT (GRSP)

Prior to the inception of the GRSP practical work at road safety improvement in Ghana was not encouraging. This was mainly due to the fact that there was not an established system of data collection, storage and analysis which by and large is crucial in understanding the nature and characteristics of our problems and discover which counter-measures to adopt in order to be able to monitor and evaluate their success or otherwise.

To develop and test an accident data system from the scratch and specifically for Ghana was not feasible within the context of the GRSP for reasons of money and time constraint. So it became necessary to look for other options.

2.1 Involvement with the Transport Research Laboratory (TRL)

The overseas unit of the Transport Research Laboratory realising the problem of accident data recording in developing countries, and the negative impact it was having on improving road safety work, developed the Microcomputer Accident Analysis Package (MAAP). This package is a low-cost easy-to-use
system with flexibility in its record format, which enables the programmes to be amended and altered to meet the specific needs and conditions of any particular country. The system consists of 8 computer programmes. Four of these are related to storage and retrieval of accident data and four are concerned with analysis of stored data. Once data has been entered into the system, various types of analysis are possible so that the character and nature of the road safety problem can be properly quantified and understood.

Main features of the MAAP:

- Cross Tabulations i.e. Accident Severity and Collision type etc.
- Link and Node Analysis
- List of Blackspots and Analysis
- Stick Diagram Analysis

The MAAP had been tried and tested in other countries and was thought to be a very convenient ready-made system which could easily be adapted and installed at minimal cost in Ghana. Hence the MAAP was installed and an Accident Analysis Unit trained at the Building and Road Research Institute (BRRI) in Kumasi.

2.2. Accident Data Collection - The New Accident Form

A new accident data collection form Fig. I was designed by the GRSP team in consultation with the BRRI and the Police and was pilot tested in the Ashanti Region of Ghana, where the BRRI is located, as part of the establishment of the accident system. The form is designed to be easy to complete and in most cases only requires the policeman/woman to select one option from a number of alternatives by encircling the appropriate item or ticking the
Fig. 1. The New Accident Report Form,
relevant box. It contains information about the site, about the vehicles and persons involved and the circumstances in the accident and location of the accident. The form is designed in two sheet, double sided format with the second sheet being an exact replica of the first sheet. After filling out, one copy of the form can be retained in the accident docket on file for prosecution, follow-up etc. along with the other relevant forms (e.g. Coroner’s report), while the second copy of the form can be sent for eventual storage and analysis at the BRRI Accident Analysis Unit.

Initially, to introduce the new accident collection forms the BRRI staffs had to visit the Police Motor Transport and Traffic Units (MTTU) in the other regions in order to ‘backcode’ data for 1988 onto the new forms so that at least one year’s data could be available for analysis nationwide and also to train the MTTU personnel on how to complete the new forms so that future accidents can be recorded on the new forms. Before each region was visited the Regional Police Commander was informed and cooperation requested. However, this process was taking longer than originally envisaged so arrangements were made to bring all the MTTU Commanders to Accra for a short training course on the forms so that the forms could be introduced nationally. Arrangements were then made for the regional commanders to send copies of forms monthly, to the National Road Safety Committee Headquarters and the BRRI for storage and analysis through the Police Headquarters in Accra. The data transfer matrix in Fig. 2 shows how data collected from the districts in every region reaches the BRRI, Accident Analysis Unit.
2.3 Data Storage – Location Systems

In order to be able to have automatic analysis and plotting of accident blackspots, it was necessary to convert street networks into coded networks for entry into the computer. A series of code numbers was devised for the road network in each region or city such that the road configuration can be represented via a numerical code. Each junction becomes a 'node' and is allocated a unique number. The section of road between nodes (called a link) is uniquely defined by specifying the nodes at each end as shown in Fig. 3.
Figure (a) shows a particular configuration of streets and Fig.(b) shows how this road system can be converted into a simple node-link network for use in accident location coding.

![Diagram](attachment:image.png)

**Fig. 3 Conversion of a street system to a coded Network**

In this way any accident location can be converted by the use of the coded node – link network into a numeric description for computerised analysis.

Available maps and plans for the major urban areas of Ghana were obtained from the survey Department in Accra for use with the accident system. For inter urban roads, maps were obtained from the Ghana Highway Authority and used to prepare 'strip maps'. These basically represent the highway as a straight line with kilometre posts and important physical features.

Each accident is stored as a single record with length dependent on the number of vehicles, passengers and pedestrians involved. The programs automatically request the data in numerical sequence and normally display the valid values which are acceptable and some logic checks included to
reject invalid values which are acceptable and some logic checks included to reject invalid combinations. Data can be coded up directly from the form in most instances. Where this is not possible, the coding manual ref. 5 is used to find the appropriate code.

3.0 DATA ANALYSIS – ROLE OF THE ACCIDENT ANALYSIS UNIT

The Building and Road Research Institute Accident Analysis Unit had a very important role to play in the establishment of the new accident data system for Ghana. First and foremost to analyse and disseminate accident data to interested parties so that the accident problems of Ghana can be tackled more systematically. Secondly, with the establishment of the Transport Research Laboratory (TRL) Accident Analysis System on its own microcomputers and the gradual storage of accident data, the BRRI now had a powerful tool for research in the field of road safety to increase the knowledge and understanding of the road safety problem in Ghana by preparing and disseminating regular reports on the accident statistics and on the location of accident blackspots to the stakeholders in Ghana as indicated in Fig. 4.

Main Achievement

Since its establishment, the Accident Analysis Unit has made considerable contributions in the effort to improve road safety which include the following:

a) Credible national accident data base established
b) Three successful Accident Blackspots Identification and Analysis Workshops organised for maintenance engineers of the Ghana
c) Many remedial interventions undertaken. Most of these have achieved significant reductions at specific locations.

d) Many customised reports on analysis prepared for agencies i.e.
   - List of accident blackspots on trunk roads
   - List of accident blackspots in the five main cities of Ghana.
• Traffic management and safety measures carried out in these
cities have been strongly influenced by this document.
• Accident characteristics by regions of Ghana
• Other special studies undertaken include
  - Bicycle safety in urban environment
  - Trunk road accidents involving disabled trucks and
    the role of advanced warning signs
  - Urban pedestrian accidents
e) Accident Blackspot Analysis and Design of Remedial measures
   completed, Implementation programme being prepared.
f) Key technical advisory input for road safety policy formulation
   implementation; National Road Safety Commission Act; Testing and
   evaluation of all road safety devices; setting standards and
   certification of traffic safety devices.

4.0 SET BACKS

A major draw back in the new system has to do with record handling by the
Police. With the successful introduction of the new accident form to the
police, it was expected that the police would eventually absorb the forms into
their record system and reprint them for subsequent uses. For some reasons
this has not happened as the police have reverted to the former system.
Possibly the new system is may be too ‘transparent’ for their liking since with
a poorly remunerated police force, there is the tendency of unethical
behaviour in handling accident cases, little wonder that they prefer the old
way of doing things. The hitch-up here is that BRRI staff have to travel to the
various stations country-wide to transfer accident data from police dockets onto the accident forms which should have been sent to the Police Headquarters through the various regional Police Commanders. This situation has subverted the expected frequency of data transfer with some registered shortfalls in collated data annually. Analysis of accidents occurring on all roads in Ghana for the period 1988 – 1993 which were reported to the police were subject to shortfalls of 45% - 55% annually. Notwithstanding these limitations, population-based surveys have generally validated the essential characteristics of the accident records.

5.0 COMMENTS AND RECOMMENDATIONS

Efforts aimed at creating a reliable database to support road safety improvements is a very costly undertaking for the weak economies of developing countries. Faced with the dilemma of providing road infrastructure to stimulate economic growth, issues pertaining to road safety are often left for future attention or presumed to be unimportant. Under such circumstances accidents are perceived as normal occurrences and not much is done to check the situation. Also, countries such as Ghana, which have adopted World Bank and other donor funded strategies of restructuring their economies have experienced appreciable improvements in their economies. Such indications are reflected in increased activity in the transport sector which is associated with worsening safety records. Rapid technological advancement in the automobile industry worldwide is introducing sophisticated cars with powerful engines not designed for the kind of roads in developing countries.
2. It has necessitated research into local accident characteristics as an essential tool in identifying and addressing road safety problems.

3. On this basis the BRRI is now able to advice and influence decisions on policy issues on matters affecting road safety which are of national concern.

References:


2. Thagesen B. Highway and Traffic Engineering in Developing Countries, 1996.


TRAFFIC SAFETY ON THREE CONTINENTS
11th International Conference
(Topic 3: Traffic safety programmes and traffic safety work on the national level)

ROAD SAFETY EDUCATION CURRICULUM FOR SOUTH AFRICAN SCHOOLS
Dr. Tiesie Drotské
Transportek, CSIR, Pretoria, South Africa

Abstract
In the past the South African school curriculum has perpetuated race, class, gender, ability, language and ethnic divisions and has emphasized separateness, rather than common citizenship and nationhood. It was therefore imperative to restructure the curriculum in order to reflect the norms, values and needs of the new democratic society. The legacy of the past has indeed left South Africa with a number of problems not least of which are that, road safety education or better known as education for life was neglected! Although it has been stated already in 1947 that the teaching and training of the learner are in vein if he/she is not also equipped for safe participation in road traffic in order to survive road safety education was not part of the previous South African educational system. Today, more than 50 years later, on the threshold of an outcomes based approach towards education, no one may ignore the cry of distress regarding the inclusion of road safety education as an integral part of the learning area, Life Orientation, in Curriculum 2005.

Research worldwide indicates that in countries where road safety education is compulsory, the accident rate is relatively low and in countries where road safety education is partly compulsory or where there is no road safety education at all the accident rate is relatively high. Road safety education thus forms the focus in the accomplishment of traffic safety and is a contributing factor in the reduction of the death toll. Over and above it has a definite role to play and deserves a rightful place within the educational system of any country. When taken into account that a curriculum is the heart of any educational process road safety education could not take place in the past because of a lack of a structured curriculum. In order to overcome this problem a comprehensive study was done from 1997 to 1999 in order to develop a core curriculum for road safety education. This paper is an attempt to spell out the value thereof.

The curriculum was developed accordingly to four parallel research processes, namely:

- Various curriculum models were studied in order to identify a model that will form the basis of the road safety education curriculation process.
- The different age and developmental phases as well as accompanying limitations of the target group were identified and specific road safety themes aimed at overcoming these limitations were selected.
- A comparative study between the curricula of 14 countries in Southern Africa and overseas were made and common road safety themes that feature prominent in the various curricula were identified.
- Questionnaires were sent out to teachers regarding the level of road safety education presently in schools and to parents regarding the young road user’s exposure to different traffic situations as well as general road safety education.
The above-mentioned processes were integrated in order to develop the core curriculum for road safety education in South Africa. This curriculum is based on the principles of co-operation, critical thinking and social responsibility, and should empower all young road users to participate safely in all aspects of society. This could best be achieved by a national curriculum which prides general road safety education as a platform for lifelong learning and contributes to the reduction of accidents, deaths, injuries and the accompanying pain and suffering.
“You taught me how to speak and write in three languages
but I do not know how to say what I feel in my heart.
You taught me how to solve maths problems
but I still can’t solve my own problems.
You taught me the names of the cities in the world
but I don’t know how to survive in the streets in my own city.
You taught me many facts – and I thank you –
But why do I have to leave school to go and learn about coping with life?”
- Anonymous (Sunday Times, 30 January 2000)

It is sometimes the honest thoughts and words of a youngster in a poem like this that brings us to a halt in order to re-think life and its value. In this regard it is particularly the South African educational system, with specific reference to the curriculum content, which are referred to. It is indeed true that mathematical problems do not weigh as much as the issue of “coping with life”. It is thus not a question of giving a child a fish but teaching him how to catch a fish.

Realising this, South African education authorities initiated a total transformation process, resulting in a new school curriculum framework for General and Further Education and Training. The challenge faced by the Ministry of Education at the dawning of a democratic society is to create an education and training system that will ensure the full development of the human resources and potential in our society.

It was imperative to restructure the curriculum in order to improve the standard and quality of education in our country, especially due to the legacy of the past. However, the need for access to life-long learning is not a South African phenomenon – South Africa is simply following international trends! Our millennium vision is to give maximum opportunity for every learner to progress to the highest level of achievement.

The new curriculum aims to reflect the norms, values and needs of a new democratic society. It is based on the principles of co-operation, critical thinking and social responsibility, and should empower individuals to participate in all aspects of society. It is flexible, appropriate and will cut across traditional divisions of skills and knowledge. The emphasis will be on what the learners should know and can do at the end of a course of learning and teaching, instead of the means that are to be used to achieve those results. The development of a new curriculum framework is a serious attempt to create a shift from the traditional input-based approach to an outcomes based approach.
This could best be achieved by a national curriculum, which prides a general education as a platform for lifelong learning. Incorporated in this curriculum is inter alia the learning area, Life Orientation, with the focus Life Skills Education. This particular field opens the door for road safety education to form an integral part thereof.

Although it has been stated already in 1947 that the teaching and training of the learner are in vein if he/she is not also equipped for safe participation in road traffic in order to survive, road safety education or better known as education for life was neglected in South Africa!

Today, more than 50 years later, on the threshold of an outcomes based approach towards education, no one may ignore the cry of distress regarding the inclusion of road safety education as an integral part of the learning area, Life Orientation, with the focus Life Skills Education in Curriculum 21.

The following table indicates the linkage between road safety education and the accident rate:

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>ACCIDENT RATE (Deaths per 100 million vehicle km traveled)</th>
<th>ROAD SAFETY EDUCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States of America</td>
<td>1.8</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Canada</td>
<td>2.9</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Denmark</td>
<td>2.6</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Finland</td>
<td>2.0</td>
<td>Compulsory</td>
</tr>
<tr>
<td>France</td>
<td>4.6</td>
<td>Partly compulsory</td>
</tr>
<tr>
<td>Federal Republic of West Germany</td>
<td>3.8</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Great-Britain</td>
<td>2.1</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>3.5</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Norway</td>
<td>2.25</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Israel</td>
<td>4.2</td>
<td>Compulsory</td>
</tr>
<tr>
<td>Turkey</td>
<td>12.0</td>
<td>Not compulsory</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>23.6</td>
<td>No</td>
</tr>
<tr>
<td>South Africa</td>
<td>16.8</td>
<td>Partly compulsory</td>
</tr>
</tbody>
</table>

(Accident rates obtained from the report of the International Road Federation, 1986, 110-117)

From the above table it appears that in countries where road safety education is compulsory, the accident rate is relatively low and in countries where road safety education is partly compulsory or where there is no road safety education at all the accident rate is relatively high. Road safety education thus forms the focus in the accomplishment of traffic safety and is a contributing factor in the reduction of the death toll. Over and above it has a definite role to play and deserves a rightful place within the educational system of any country.
When taken into account that a curriculum is the heart of any educational process road safety education could not take place in the past because of a lack of a structured curriculum. In order to overcome this problem a comprehensive study was done from 1997 to 1999 in order to develop a core curriculum for road safety education. This paper is an attempt to spell out the value thereof.

This curriculum was developed accordingly to four parallel research processes, namely:

- **Literature study:** various curriculum models (Tyler, Taba, Wheeler, Nicholls & Nicholls, Oliva, Littrel & Bailey, Jansen, Walters, Cawood-Carl-Blanckenberg, Kruger, Steyn) were studied in order to identify a model that will form the basis of the road safety education curriculation process. The outcome of this was the identification of the Kruger model to serve as the basis for developing the road safety education curriculum. The following is a schematic approach to the Kruger model:

- **Literature study & Questionnaires:** The different ages (5 – 18 years), developmental phases (pre-school child, pre-adolescence and adolescence) and school phases (grade 0, foundation phase, intermediate phase, senior phase) were identified according to accompanying limitations of the specific target group. Road safety themes aimed at overcoming these limitations were selected. Questionnaires were sent out to parents and teachers of learners in order to get feedback regarding their knowledge of the limitations of children during traffic participation. The following serves as an example of the pre-school road user (Grade 0, 5-6 years) in this regard:
According to each limitation with regards to the behaviour of the young road user, certain road safety themes were incorporated in the curriculum in order to help children to deal and overcome their limitations. An example based on the above-mentioned is:

- Height: limits his vision, see and be seen, can not cross street between parked vehicles
- Visual blindness, limited peripheral vision & low eye level
- Poor memory, memorizing without insight, illogical reasoning ability, inability to think abstractly, poor decision making skills
- Limited sensitivity for sounds, limited ability to locate sound
- Ego-centeredness, self-centeredness
  Impulsiveness, increased vitality, curiosity, fickleness, willfulness, unpredictability
- Poor hand dominance
- Rushing out as a result of limited social skills
- Interpretation and meaning of traffic signs
  Rules applicable to passengers in a car, taxi, bus
  Rules applicable to pedestrians and cyclists
  Distinguish: right vs wrong
- Listening to traffic sounds
  Auditory skills
- Safe places to play
  People who can help
  How, where and when to cross a street
  Attitudes: obedience, courtesy, responsibility
- Danger regarding parked and reversing vehicles
- Looking in all directions
  Visibility
  Interpretation of stimuli
  Crossing a street
  Visual skills
- Poor hand dominance
- Dangers and risks
  Pedestrian facilities
  Gross motor skills
  Fine motor skills
A comparative study was made between the curricula of 14 countries in southern Africa and overseas and common road safety themes that feature prominently in the various curricula were identified. The 14 countries were:

- United Kingdom
- Belgium
- Zimbabwe
- Austria
- Denmark
- Estonia
- Spain
- France
- United States of America
- Israel
- New-Zeeland
- Germany
- Japan
- Netherlands

From this comparative study the following categories were included to serve as main themes in the curriculum:

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Road Safety Education Curriculum

Traffic Environment    Pedestrian    Passenger    Cyclist    Driver    Perceptual skills    Attitudes

Development & Limitations
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For each of the above-mentioned categories content was developed. The following serve as an example of the Pedestrian component within the curriculum for Grade 0:

<table>
<thead>
<tr>
<th>PEDESTRIAN EDUCATION</th>
<th>Walking safely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Differences between urban and rural areas</td>
</tr>
<tr>
<td></td>
<td>Rules applicable to pedestrians</td>
</tr>
<tr>
<td></td>
<td>The interpretation and meaning of traffic signs applicable to pedestrians</td>
</tr>
<tr>
<td></td>
<td>Visibility and conspicuous clothing</td>
</tr>
<tr>
<td></td>
<td>Dangers and risks</td>
</tr>
<tr>
<td></td>
<td>Effect of weather conditions</td>
</tr>
<tr>
<td>How, where and when to cross a street</td>
<td>The danger regarding parked and reversing vehicles</td>
</tr>
<tr>
<td></td>
<td>How to use a pavement or footpath</td>
</tr>
<tr>
<td></td>
<td>How to walk safely next to the street or road</td>
</tr>
<tr>
<td></td>
<td>Traffic lights for pedestrians</td>
</tr>
<tr>
<td></td>
<td>Block pedestrian crossing</td>
</tr>
</tbody>
</table>

NB: Above-mentioned are taught to the learner, but it is recommended that the learner only apply it under adult supervision. It is therefore a preparatory process.

Questionnaires were sent out to teachers and parents regarding the young road user’s exposure to different traffic situations as well as training in general and specialized road safety education. The following results were found:

- It was found that most teachers did not receive training in road safety education during the initial formal professional training or in-service training. Teachers neither received any other training of this nature. The result of this is that the majority of teachers are not trained and equipped to offer road safety education. The average response considering the training in road safety education of parents of learners in the various school phases also indicated that parents received no training of any kind for offering road safety education to their children.

- Although teachers are not trained to present road safety education teachers in all three relevant school phases indicate that "reasonably many" lessons are devoted to road safety education.

- It was also found that teachers responsible for grade 0, the foundation phase and intermediary phase "sometimes" use teaching media and that a traffic official was invited "reasonably often" to pre-primary schools and "sometimes" to primary schools.

- Road safety awareness days and/or weeks takes place "reasonably often" in pre-primary schools and "sometimes" in primary schools. With regard to road safety awareness days the situation in pre-primary schools appears to be more favourable than that in primary schools, where a stronger negative response regarding traffic safety awareness activities was given.

- It was found that the themes "how and where to cross a road/street" and "rules for pedestrians" showed the highest user frequency in all three school phases.
Themes relating to safe cycling, namely "the use of hand signals during cycling" and "rules for cyclists" shows the lowest user frequency in all three school phases.

- Teachers take grade 0 learners "reasonably often" for practical work sessions in the real traffic situation, while parents of grade 0 learners and teachers of learners in the foundation phase and intermediary phase "sometimes" take learners for practical work sessions. A predominantly negative response was therefore given in this regard.

- It was found that young road users in all three the relevant school phases were exposed in the presence of their parents mostly to situations where they were confronted with "the use of safety belts" and the "crossing of a road/street". Learners in all three the school phases are exposed least to "the use of a tricycle/bicycle" and "the learning of hand signals" in the presence of their parents during traffic participation. Learners in grade 0 are confronted in the absence of their parents mostly with "safe places to play" and "the use of safety belts". Grade 0 learners are exposed least to "the use of a tricycle" and "situations where rules for bicycles must be applied" in the absence of their parents. Learners in the foundation phase and intermediary phase are exposed in the absence of their parents mostly to "the crossing of a road/street" and "situations where basic traffic rules must be applied". The same group of learners are confronted least with "situations where hand signals must be displayed during cycling" in the absence of their parents. From this it follows that grade 0 learners are both in the presence and absence of their parents exposed mostly to "the use of safety belts" and "safe places to play" and least to "the use of a tricycle" and "situations where rules for cyclists must be applied". Learners in the foundation phase and intermediary phase are confronted both in the absence and presence of their parents mostly with "the crossing of a road/street" and "the use of safety belts". Second to this, grade 0 learners and learners in the foundation phase are exposed mostly to situations where they must take decisions about "safe places to play". These three situations therefore show the highest frequency in all three relevant school phases. Learners in the foundation phase are exposed least to "situations where hand signals must be displayed during cycling", "situations where rules for cyclists must be applied" and "different destinations to which he travels by bicycle". Learners in the intermediary phase in turn are confronted least with "situations where hand signals must be displayed during cycling" and "situations where the child carries out dangerous actions and experiences the results". It appears that the total population of learners is exposed both in the absence and presence of their parents least to "the use of a tricycle/bicycle" and "the application of hand signals during cycling".

- Parents teach grade 0 learners most about "safe places to play", "the use of safety belts" and "positive attitudes towards road use" and least about "where to ride with a tricycle". It became clear in the above that the latter theme is also the situation to which grade 0 learners are exposed least both in the absence and the presence of their parents. Parents of learners in the foundation phase teach their children most about "safe places to play", "how to cross a road/street" and "the use of safety belts" and least about "rules for cyclists" and "the learning of hand signals". In this light it can be said that parents of learners in the
foundation phase teach their children most about "how to cross a road/street", "safe places to play" and "the use of safety belts". Compared to this, "the learning of hand signals" and "rules for cyclists" is taught least. Learners in the foundation phase are exposed respectively the most and the least in both the absence and the presence of their parents to these situations. In the intermediary phase parents teach their children most about "how and where to cross a road/street" and "the use of safety belts". This group of learners is taught least about "rules for cyclists" and "the learning of hand signals". Themes about which parents teach their children in this phase most and to which they are exposed most in both the absence and the presence of the parents, are "the crossing of a road/street" and "the use of safety belts". A theme about which parents teach their children least, and to which children are also exposed least both in the absence and presence of parents in the relevant school phase, is "the learning of hand signals during cycling". Common themes which are taught most in all school phases and to which learners are exposed most in both the absence and presence of parents, are "the crossing of a road/street", "safe places to play" and "the use of safety belts". It was found that parents teach cycling education to their children least with specific reference to "the use of a tricycle" in grade 0 and "the learning of hand signals" in the primary school. Apart from this, respondents also indicated that learners in all school phases are exposed least to these themes both in the absence and presence of their parents.

- The average opinion of parents and teachers of learners in all three relevant school phases is that they have "reasonably much" knowledge of the possible limitations experienced by young road users in traffic situations. This indicates a predominantly "average" rate of response. (As a measure of control for the above finding, questionnaires made provision for respondents to mention at most two alternative limitations of road users in grade 0, the foundation phase and intermediary phase. Fewer than a third of teachers and parents of learners in the relevant school phases reacted to this, the exception being parents of grade 0 learners, of whom 44.83% responded.) The conclusion is that only a minimum number of respondents on the one hand understand the concept "limitation" and on the other hand show insight in the limitations of young road users during traffic participation. It should, however, be mentioned that respondents who did respond to this, offered sensible reactions.

- Parents of learners in all school phases agree that they can describe as "reasonably adequate" their knowledge about limitations, which make children vulnerable in the traffic situation.

- All teachers and parents of learners in grade 0, the foundation phase and intermediary phase are of the opinion that parents and the school are "definitely" responsible for Road safety education. Teachers for grade 0 and the foundation phase as well as parents of learners in the foundation phase are of the opinion that traffic safety authorities "definitely" are responsible for Road safety education, while teachers and parents of learners in the intermediary phase and parents of learners in grade 0 are of the opinion that traffic safety authorities are responsible for Road safety education only "to an extent". Teachers for the foundation phase responded that traffic officials are "definitely" responsible for Road safety education, but other teachers and parents are of the opinion that
traffic officials are responsible for it "to an extent". Teachers and parents of grade 0 learners are of the opinion that the church is "not at all" responsible for Road safety education, while teachers and parents of learners in primary schools are of the opinion that the church is responsible for Road safety education "to an extent".

- The average response of teachers and parents of learners in grade 0, the foundation phase and intermediary phase indicates that Road safety education is regarded as "essential" for all children. Teachers of learners in the intermediary phase respond that the current Road safety education practice is "totally inadequate". All other teachers and parents describe the current practice in schools as "reasonably adequate", which indicates a predominantly average response, compared to the former negative response. All respondents (i.e. teachers and parents of learners in grade 0, the foundation phase and intermediary phase) agree that the ideal Road safety education practice should be "compulsory" for all learners. What is striking about the general remarks and comments, which respondents could make, is the plea for Road safety education to be incorporated in the school curriculum and to be compulsory for all learners in all school phases. Based on this, it may be said that the importance and necessity of Road safety education is generally recognised.

The above-mentioned ingredients of the overall research processes were integrated in order to develop the core curriculum for road safety education in South Africa. Common and high frequency factors were identified and incorporated. This curriculum is based on the principles of co-operation, critical thinking and social responsibility, and should empower all young road users to participate safely in all aspects of society. This could best be achieved by a national curriculum which prides general road safety education as a platform for lifelong learning and contributes to the reduction of accidents, deaths, injuries and the accompanying pain and suffering. Education and training are indeed central activities of our society. Road safety education as an integral part thereof is of vital interest to every family, community and to the health and prosperity of our national economy. Let us all contribute not only to teach our children “the names of the cities in the world” let us strive towards effective road safety education and intensively teach them “how to survive the streets of their own cities…”

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1. Introduction

One of the main traffic problems is to ensure the safe traffic in the roads and streets. A number of motor vehicles is increasing in Lithuania (Figure 1). Lithuania has about 3.7 million inhabitants and about 1.2 million motor vehicles. Traffic intensity, which has grown to a considerable extent, causes many difficulties in ensuring safe traffic. In Lithuania during the period 1980-1999 years 15529 people were killed in road traffic accidents and 104698 were injured. It is registered from 5 to 7 thousands of traffic accidents every year, during which people suffer. About 60 children are killed in traffic accidents per year and almost 1000 become invalids. Solely during 1999 there were 748 fatal casualties and 7696 people were injured. Annual traffic accidents loss makes up about 325 million USD. Besides, great moral losses are suffered.

Fig. 1. Number of motor vehicles per 1000 population in 1981-1999.

2. Analysis of road traffic safety

The analysis of the number of traffic accidents in Lithuania during the past 20 years shows, that this period can be divided in 4 periods. First in year 1978-1986 the amount of traffic deaths was slightly decreasing. Secondly, in year 1987-1992 traffic deaths and injury has increased (1.8 times) at a sharp rate. Thirdly in years 1992-1996 the amount of traffic deaths was slightly decreasing, but again increased in 1997, especially increased theumber
of injured people. Dynamics of number killed and injured 1980-1999 in Lithuania represented in table 1 and figure 2.

Fig 2. Dynamics of number killed and injured in Lithuania 1989-2000 (1980 = 100%: black – killed, white – injured)

Table 1. Distribution of road traffic accidents and casualties in 1990-1999.

<table>
<thead>
<tr>
<th>Year</th>
<th>Accidents</th>
<th>Injured</th>
<th>Killed</th>
<th>Vehicles</th>
<th>Cars</th>
<th>Killed /1 mln. vehicles</th>
<th>Killed /1 mln. population</th>
<th>Killed /100 injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>5135</td>
<td>5491</td>
<td>933</td>
<td>622098</td>
<td>492978</td>
<td>1500</td>
<td>250</td>
<td>17,0</td>
</tr>
<tr>
<td>1991</td>
<td>6067</td>
<td>6638</td>
<td>1093</td>
<td>657642</td>
<td>530824</td>
<td>1662</td>
<td>292</td>
<td>16,5</td>
</tr>
<tr>
<td>1992</td>
<td>4049</td>
<td>4251</td>
<td>779</td>
<td>693097</td>
<td>565320</td>
<td>1124</td>
<td>208</td>
<td>18,3</td>
</tr>
<tr>
<td>1993</td>
<td>4319</td>
<td>4556</td>
<td>892</td>
<td>727281</td>
<td>597735</td>
<td>1226</td>
<td>240</td>
<td>19,3</td>
</tr>
<tr>
<td>1994</td>
<td>3901</td>
<td>4147</td>
<td>764</td>
<td>763506</td>
<td>652810</td>
<td>1001</td>
<td>204</td>
<td>18,4</td>
</tr>
<tr>
<td>1995</td>
<td>4144</td>
<td>4509</td>
<td>671</td>
<td>836943</td>
<td>718469</td>
<td>801</td>
<td>179</td>
<td>14,9</td>
</tr>
<tr>
<td>1996</td>
<td>4576</td>
<td>5223</td>
<td>667</td>
<td>905122</td>
<td>785088</td>
<td>734</td>
<td>176</td>
<td>12,7</td>
</tr>
<tr>
<td>1997</td>
<td>5319</td>
<td>6198</td>
<td>725</td>
<td>1005807</td>
<td>865032</td>
<td>837</td>
<td>195</td>
<td>11,7</td>
</tr>
<tr>
<td>1998</td>
<td>6445</td>
<td>7667</td>
<td>829</td>
<td>1087880</td>
<td>942369</td>
<td>762</td>
<td>224</td>
<td>10,8</td>
</tr>
<tr>
<td>1999</td>
<td>6356</td>
<td>7696</td>
<td>748</td>
<td>1115964</td>
<td>957652</td>
<td>672</td>
<td>202</td>
<td>9,7</td>
</tr>
</tbody>
</table>

The analysis of traffic accidents, which took place in Lithuania in 1996-1999, and during which people were killed and injured, shows that the main types of accidents are as follows: knocking down pedestrians and cyclists, collision of cars, collision to obstacles, to cart, to standing means of transport, overturning and others. Almost every second accidents are collision between pedestrian and vehicle. It makes about 40% of all casualties. Collision between pedestrian and vehicle generally occurs at night time.

The distribution of culprits of traffic accidents is represented in table 2. In the traffic accidents, during which people were killed or injured, drivers were guilty (about 60%), 2/3
of them being drivers of motor cars. More than one third of road accidents happens through drivers', whose length of driving does not exceed 4 years. That shows that a level of training of drivers should be improved.

After analyzing the distribution of fatal casualties and the injured between the traffic participants it is seen that about 40 % pedestrians suffer in car accidents (table 3). The distribution of traffic accidents in the streets of towns and in the roads is represented in table 4. This information shows that more than a half of accidents takes place in streets of towns.

A number of killed in road accidents per million persons were 202 people and fatalities per million motor vehicles were 672 people. A number of killed per 100 injured were 10 people (table 1). In spite of a lower motorization level in Lithuania than in many developed European countries, there indexes of traffic accidents are several times worse than in others countries of Europe.

Table 2. Culprits of traffic accidents.

<table>
<thead>
<tr>
<th>Culprits of accidents</th>
<th>Number of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1994</td>
</tr>
<tr>
<td>Drivers</td>
<td>2278</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>1223</td>
</tr>
<tr>
<td>Cyclists</td>
<td>326</td>
</tr>
<tr>
<td>Others</td>
<td>75</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>3902</strong></td>
</tr>
</tbody>
</table>

Table 3. The distribution of fatal casualties between traffic participants.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Numb.</td>
<td>%</td>
<td>Numb.</td>
<td>%</td>
<td>Numb.</td>
<td>%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>358</td>
<td>40,1</td>
<td>323</td>
<td>42,2</td>
<td>238</td>
<td>36,0</td>
</tr>
<tr>
<td>Drivers</td>
<td>243</td>
<td>27,2</td>
<td>175</td>
<td>22,9</td>
<td>173</td>
<td>26,0</td>
</tr>
<tr>
<td>Passengers</td>
<td>185</td>
<td>20,7</td>
<td>170</td>
<td>22,2</td>
<td>173</td>
<td>26,0</td>
</tr>
<tr>
<td>Cyclists</td>
<td>100</td>
<td>11,2</td>
<td>86</td>
<td>11,2</td>
<td>75</td>
<td>11,0</td>
</tr>
<tr>
<td>Others</td>
<td>7</td>
<td>0,8</td>
<td>11</td>
<td>1,4</td>
<td>8</td>
<td>1,0</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>893</strong></td>
<td><strong>100,0</strong></td>
<td><strong>765</strong></td>
<td><strong>100,0</strong></td>
<td><strong>667</strong></td>
<td><strong>100,0</strong></td>
</tr>
</tbody>
</table>
Table 4. The distribution of traffic accidents in streets and roads.

<table>
<thead>
<tr>
<th>Place</th>
<th>Number of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1994</td>
</tr>
<tr>
<td>Urban roads</td>
<td>1969</td>
</tr>
<tr>
<td>Others settlements</td>
<td>248</td>
</tr>
<tr>
<td>Main roads</td>
<td>470</td>
</tr>
<tr>
<td>National roads</td>
<td>508</td>
</tr>
<tr>
<td>Regional roads</td>
<td>606</td>
</tr>
<tr>
<td>Local roads</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>3901</strong></td>
</tr>
</tbody>
</table>

3. The main reasons of traffic accidents

When was made the analysis of traffic accidents in Lithuania in 1980-1997 in which was investigated the kind of traffic accidents, their culprits and situations, the amount of fatal casualties and injured distribution between participants of traffic and having estimated the experience of foreign countries was established the main reasons for high level of development of car accidents in Lithuania:
- not perfect and incompletely finished the legal basis of road traffic safety;
- there is no unified road traffic system and structures which would ensure effective coordinate work of all the sections;
- there is no unified road traffic safety information system;
- unsatisfactory infrastructure of roads and streets;
- very bad traffic participants’ behavior and discipline; society is not involved in discussing road traffic safety problems;
- very low financing of the work of road traffic safety;
- ineffective control of road traffic; the work of police is insufficiently oriented to disclosing the most dangerous infringements and to prevention of infringements;
- not perfect safe traffic training system;
- there is no system for preparing and perfecting road traffic safety specialists;
- ineffective of rescuing and first aid;
- local governments (especially in districts) are very passive and they do not take part in ensuring safe road traffic in streets and local roads;
- unfinished system of control of means of transport and their exploitation;
- there is no law for the obligatory drivers’ civil responsibility insurance;
- not perfect drivers’ training system;
- ineffective propagandize activity of traffic safety;
- insufficiently collaboration with foreign and international organizations of traffic safety;
4. The main measures of improving traffic safety

Having estimated very bad traffic safety conditions in Lithuania and the finance possibilities of our country and having estimated the experience of foreign countries, it were suggested the measures for improving traffic safety:
- developing the public cities’ transport;
- improving the legal basis of traffic safety;
- to make and develop the general computer information system of traffic safety;
- to organize training of all traffic participants, to form the importance of road traffic safety in society;
- to organize the system for preparing and perfecting road traffic specialists;
- to improve the system of drivers’ training;
- to develop propagandize and agitation in field of road traffic safety;
- to prepare and realize measures of improving road traffic safety in roads and streets;
- to renovate the scheme of road traffic organization in the biggest cities of Lithuania;
- to strengthen the control of road traffic in roads and streets;
- to establish the system of rescuing and first aid in the main highways;
- to improve the quality of the means of transport and their exploitation;
- to prepare the law of road traffic;
- to prepare the program of controlling alcohol for drivers;
- to analyze the establishment of traffic safety program in 1997-2000;
- to establish traffic safety services in districts and local governments;
- to prepare the law for the obligatory drivers’ civil responsibility insurance;
- collaborate more with foreign and international organizations of traffic safety;

In order to improve road traffic safety in Lithuania, the road traffic safety program for 2001-2005 was prepared. The essential aim of this program is to reduce the number of fatal casualties by 25 %.

Literature

The following paper is based on work carried out by a team including the authors and F. Châtenet (INRETS), B. Chekarao, M. Fatonzoun (SITRASS), S. Lassarre, J. L’Hoste, F. Piozin, F. Saad, (INRETS) M. Truffier (ISTED), E. Yoro (SITRASS)

Introduction

At the end of 1999, UEMOA, the Economic and Monetary Union for West Africa, launched a study of the road safety situation and management processes in seven of the eight countries of the Union (Bénin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Sénégal, Togo), in view of formulating Communal Road Safety Policies at the regional level. The study was funded by the European Union. A team of African and European “experts” was formed to establish a diagnosis on each country as well as a global assessment of the situation in the region, and to draw proposals for action. The final report was published in March 2000 and is now being evaluated by UEMOA and integrated into a wider proposal for transport policies, for presentation at a round table of donors.

The present paper does not provide a complete summary of the outcome of the study, but presents a selection of some difficult problems encountered in the countries investigated and directions for possible solutions as seen by the researchers and consultants that took part in the study. Comprehensive proposals and guidelines for Communal Road Safety Policies are not included as they have not officially been accepted by UEMOA yet, but the original report can be requested from this organisation in Ouagadougou. A brief outline of the approach and methodology used is described. More complete methodological guidelines, developed from the experience gathered through the UEMOA study as well as previous ones carried out by Inrets (the French National Institute for Transport and Safety Research) will be published at a later stage.

Objectives of the study

The study aimed at planning Communal Road Safety Policies for the countries in the UEMOA Region. In order to do this, a diagnosis of the road accident and injury situation in each of the eight countries was found necessary as well as an assessment of their organisations for road safety management and identification of possible changes or improvements to be made at the national level.

Communal Road Safety Policies were intended as a useful complement to national road safety efforts. As such, they were defined as serving three main purposes:

1. Encouraging, promoting and facilitating the development of national safety policies in the eight countries of the Union by organising communication and exchanges of experience on key issues of interest to all, possibly organizing pilot actions on specific issues, and following up implementation of recommended strategies and their effects.
2. Harmonizing road safety action taken in the eight countries when needed in view of mobility of populations or road users across their borders; regulations, education and driver training are particularly relevant areas, but road design and maintenance procedures on the international road network need also be considered.

3. Putting research as well as methodological, technical, and training resources in common whenever possible in order to avoid duplication of investments, provide common guidelines and optimize the use made of such tools.

In addition, some attention was given to issues of particular interest to a community of countries such as safety of the international road network linking them.

The necessary institutional developments as well as means and tools needed to implement the Communal Road Safety Policies were to be analysed and proposals made. Budgetary and financial procedures and needs were examined whenever possible, but a complete assessment of the funding requirements involved could not be made with the time and means allocated.

**Methodological approach**

1. **Country diagnoses**

The safety diagnoses carried out on each of the seven countries investigated covered six areas:

a) Basic tools available for road safety information and management: availability and reliability of accident and injury data, of other relevant data (population, economy, traffic, infrastructure, etc.), institutional management of the data collection systems, needs for improvement and/or development, needs for technical or methodological tools, needs for training.

b) Current road accident and injury situation, as drawn from existing data as well as previous studies: overall assessment, main characteristics in terms of accident types, road users involved, geographical distribution, risk factors, accident or injury causation factors in urban areas and on rural roads, etc.

c) What was termed as "fundamental" or "structural" actions: measures or strategies necessary to ensure smooth functioning of the infrastructure and transport system (including, of course, increased safety), but involving long term organisation and therefore not aimed at an immediate reduction of accident and injury rates: road user training and licensing, traffic education, traffic regulations and enforcement, transport regulations, road user information.

d) "Corrective" or remedial actions: measures or strategies primarily aimed at reducing the amount of injuries already observed on the roads: safety measures and plans in urban areas, safety measures and strategies on rural roads, measures addressing vehicles, rescue and treatment of accident victims.

e) Organisation of road safety management: public and private actors and institutions involved, their relationships, coordination and road safety planning at the national level, the difficulties encountered, needs for methodological and technical tools and assistance, needs for training.

f) Study and research resources: identification of research and/or study teams, results from previous studies in road safety or related fields, interactions with the road safety management system.

Diagnoses were carried out in each country by separate sub-teams including national and French experts. In order to ensure comparability of the diagnoses, a detailed checklist of information to be gathered
in the five areas described was drawn. Part of the information wanted was found from legal or administrative documents and, in some countries, from previous studies recently performed by team members; as an assessment of the real conditions of road safety management was needed, interviews with persons identified as key road safety actors in their countries were also carried out; in the present state of road safety organisation in UEMOA countries, it was found that drawing a reliable road safety diagnosis involved interviewing high level professionals in most of the sectors of activities concerned: transport, enforcement, roads, health, emergency rescue, studies and research.

The information collected was processed in order to provide a faithful, if summary, image of road safety conditions and management in each country, and areas for improvements were identified.

2. Comparison of findings and proposals for Communal Road Safety Policies

The findings from the country diagnosis were compared in each of the six areas. Common characteristics and problems were identified in view of suggesting similar courses of action in the eight UEMOA countries and guidelines for the regional road safety policies. On issues of interest to all, the countries most advanced or with interesting experience were identified as possible "pilot-countries" for future action. Differences in road safety management were also assessed, either when creating problems at the regional level and thus justifying some effort at harmonization, or when providing examples of strategies that could be adapted in other countries. Finally, the types of resources required for improvements of national road safety management systems were compared in order to identify those that could be provided and maintained at the communal level.

Main findings

1. Accident data management

In the seven countries investigated, accident reporting is performed according to similar procedures by the law enforcement agencies, the urban police in the larger cities and the "gendarmerie" (military police) on rural roads. Injury accident reporting is noticeably uncomplete in all countries for a variety of reasons: some of the road users involved come to an agreement and do not call the police (Bénin, Mali, Togo), means of transport and other resources allocated to the law enforcement agencies are not adequate for the task, which means that accidents notified are not always reported (Côte d'Ivoire, Mali, Sénégal), the road users are asked for a fee to obtain a report and are not always willing to pay (Burkina Faso) or are simply not inclined to involve the law. Furthermore, severity of reported accidents is usually underestimated as the law enforcement officers do not have the means to follow up the health condition of accident victims for a few days after the event and a significant proportion of fatalities are thus not counted.

A standard accident statistical form has been designed in all countries except Niger at various times between 1984 (Côte d'Ivoire) and 1999, but there has been no harmonization of the data content and structure so far. There is still scope for developing a common core for accident forms in order to produce some comparable accident statistics; this will should be negotiated at the regional level between regional and national authorities and representatives the field actors involved in each country (data users and managers, law enforcement officers).

However, the main problem at the moment lies in centralizing the statistical data at the national level: while the gendarmerie operates with a formal hierarchy that provides natural channels to check and gather data from the local level upwards, accidents and injuries reported by the urban police seldom reach the national agency in charge of producing road safety statistics. To overcome this problem, some countries (Côte d'Ivoire, Sénégal) have organised, at least for a transitory period, specific teams to collect the data all
around the country at regular intervals; however, such procedure is not always easily accepted by the law enforcement officers and it is difficult therefore to make sure the data is all in.

Most of the problems encountered are generated or amplified by insufficient communication between the actors requesting and using accident and injury data (roads and transport sectors, study and research agencies, etc.) and those originally producing them (the law enforcement agencies) as well as the absence of a formal status of the national accident statistics.

Developing a reliable accident data collecting system in the UEMOA countries obviously requires allocation of greater resources, both human and material, at different levels of the data production chain (investigating and reporting accidents, filling in statistical forms, centralizing data, processing data), better provisions for periodical training of the officers involved, and wider dissemination of the statistics obtained in order to keep spirits up all along the operational chain. It also requires setting up some new institutional links for discussion and improvement of the content and quality of the information collected and for easier and faster circulation of the data. Finally, the data must be made more easily available to all those needing it for road safety tasks. This will not happen without a strong political will at the national level, which can be induced or supported by efforts at the communal level.

2. The road accident and injury situation

Given the current poor quality of accident and injury recording, it is very difficult to draw an accurate road safety diagnosis at the national level and even more to compare situations between the seven countries investigated. However, based on subsets of data and on some ad'hoc safety studies (in Côte d'Ivoire, Niger, Burkina Faso, Abidjan in Côte d'Ivoire, Bamako in Mali, Dakar in Sénégal, Lomé in Togo), some common problems can be identified:

a) Road safety in urban areas is a major issue, particularly in the large cities with a high level of motorisation (as, for instance, Cotonou in Bénin, Ouagadougou in Burkina Faso, Abidjan in Côte d'Ivoire, Bamako in Mali, Dakar in Sénégal, Lomé in Togo), but also in smaller towns where through traffic conflicts with local activities. The main accident fatalities are pedestrians, of which over 40% are children under 14. In Cotonou, Ouagadougou, Lomé, where two-wheeler traffic is important, motorbike safety is also an issue. Most of the serious accidents appear to occur on large urban arteries with mixed traffic and mixed usage of part of the road space, where speeds may be high, junctions are usually under-equipped and provisions for pedestrian crossings are grossly insufficient.

b) On rural roads, the higher density of serious accidents is naturally observed on the primary road network, including the interstate routes, where traffic is heavy, speeds are high and safety equipement poor. Professional vehicles (buses, minibuses, vans, lorries) are most often involved (which does not necessarily imply that they are more at risk than others). Severity of accidents involving vehicles transporting simultaneously people and goods is particularly high and a few "catastrophical" accidents, generally happening to public transport vehicles (which makes for a large number of fatalities), may account for a significant portion of the overall victims count.

The accident factors most frequently identified through ad'hoc safety studies or acknowledged by local professionals include:

- behavioural problems: speeding or inadequate speeds in relation to the traffic environment, lack of compliance with regulations (Stop, priorities, overtaking), insufficient attention to pedestrians, inadequate positioning on the road for turning movements, fatigue and loss of vigilance; it is to be noted that some of these factors are often related to a poorly designed road environment inducing misunderstandings and mistakes by the road users, while others are induced by hard working conditions.
- vehicle problems : overloading, mixed transport, insufficient maintenance of safety features (tyres, headlights, brakes) ; such factors may reflect on the behaviour of vehicle owners, but are usually also related to the constraints of professional transport.

- infrastructure problems : in urban areas, lack of pedestrian facilities, poor street lighting, underequipped junctions ; on rural roads, dangerous curves and junctions, lack of adequate shoulders, insufficient signing and marking, deterioration of the road surface resulting from infrequent maintenance.

Drinking-and-driving is not systematically checked and is not considered an issue, at least in some of the countries investigated, due to the local way of living, but drug taking, especially aimed at keeping awake and driving longer, is suspected to be a significant accident factors on rural roads (for example in Niger), although there are no means available to assess drug consumption.

Some of the behavioural accident factors identified point out to the fact that the "fundamental" measures have fallen behind and need to be developed in order to change behaviour and improve professional transport conditions. Other factors call for "corrective" action including infrastructure improvements (design, signing and marking, maintenance) on the primary road network as well as on urban throughfares, speed management, implementation of pedestrian safety facilities. The latter is particularly at stake in the cities where traffic plans are being developed as pedestrian traffic needs to be taken into account at an early stage.

Improving safety conditions thus requires combined long-term and short-term efforts addressing not only the road users but also their infrastructure environment. Although road safety problems in urban areas may not be directly managed by national governments, they are too important to be neglected and have to be included in national safety policies.

3. "Fundamental" or "structural" action

Emphasis has been put here on issues on which improvements are workable or are deemed urgent. Other important issues, such as regulation and organisation of professional transport and driving, have been tackled in the study, but have been omitted in this paper as possible solutions involve economic issues and will require long term consultations and discussions, both at the national and the international level, in order to reach a consensus.

3.1. Traffic regulations

The Highway Code is ancient in all seven countries and needs to be clarified and added to, particularly with regards to dispositions on pedestrians rights and mobility rules, on provisions for enforcement, and on the level of fines. The law is being revised in Niger, Mali and Togo.

All countries have speed limits in urban areas, varying from 40 to 60 km/h, but there is little compliance from drivers and enforcement is nonexistent. Speed limits on rural roads vary according to type of infrastructure and type of vehicle, but Bénin and Togo still do not have them. Again, compliance is low and enforcement is only performed periodically. Mandatory seat belt wearing is effective only in Côte d'Ivoire and Togo and not enforced. Helmet wearing for motorised two-wheelers is mandatory in all seven countries, but seldom enforced. There is a legal maximum blood alcohol content for drivers of 0.8 g/l in all countries except in Burkina Faso (no law) and in Bénin (where a 0.5 g/l limit is enforced without having been legalized).

Periodical technical checks of vehicles are mandatory in all UEMOA countries, but are performed through different channels ; in Côte d'Ivoire, for example, monopoly of the technical checks has been allocated to a private organisation, equiped with all the necessary technical tools; in Niger,
Sénégal, Togo, the transport administration performs the checks with rudimentary means; this was also the case in Mali until recently when a private firm was granted monopoly of the checks in the capital city. In Bénin, the National Road Safety Centre performs the tests in several cities with variable levels of specialised equipment. Whatever the organisation, the fleet of vehicles is not wholly covered and the effects obtained are not all that encouraging: vehicle defects still appear as major factors in accidents and enforcement agencies spend a lot of their time on the roads checking tyres or vehicle lighting and finding faults even in vehicles displaying a periodical check certificate. More attention should be given as to the basic reasons that make drivers or vehicle owners neglect maintenance of their vehicle, reasons which are not addressed by periodical checks.

3.2. Enforcement

In all UEMOA countries, enforcement is simply not working. Most of the safety regulations are not enforced, as mentioned earlier, and efforts concentrate on checks of vehicles and administrative papers which can be performed at fixed locations. Misuse of power is the current practice of traffic law enforcement agencies, to the point that enforcement has now been completely stopped in several countries or cities (in Abidjan, in Togo), under the pressure of transport professionals that have started protesting the inequity of the procedures: in actual facts, the issue of inequity and the corrupted image of enforcement agencies have obliterated all the useful aspects of law enforcement in the eyes of the public. It must be said that attitudes and practice of law enforcement personnel is greatly influenced by the fact that they are underpaid and provided with very little means to perform their task. However, the situation has now reached a point where it will not be easy to straighten out.

In Côte d'Ivoire, OSER, the Road Safety Office, has organised special brigades working, in cooperation with the law agencies, on enforcement of speed limits and is preparing to do the same with drinking-and-driving laws. Although the new procedure seems to have had a positive effect on driver behaviour (no formal evaluation has been carried out), it cannot be extended over the whole country with the current resources available, and it raises some institutional opposition. However, the example is worth following up and some larger scale and more formal organisation could be drawn from it.

Whether enforcement is reorganized within the law enforcement agencies or with the intervention of another network, related to the transport administration or to traffic safety institutions, new personnel with more time devoted to safety issue, better training, better working conditions and adequate working equipment will be needed. Information of the public will be essential to make sure the changes and new attitudes are known and recognized.

3.3. Driver training and licensing and road user education

Although, in all UEMOA countries, the licensing laws follow a similar progression according to type of motor vehicle and its usage (private, commercial), there is a wide diversity of dispositions that make it easier to get a license in some countries and encourage future drivers in others to get their exams abroad: in Niger, for example, it is particularly difficult to obtain a license to drive lorries or buses and a fair proportion of Nigerien professional drivers own a license from Côte d'Ivoire. For safety purposes, some harmonization is needed, but it will reflect on the organisation of driver training and the licensing exams as, for example, a greater variety of vehicle types, including heavy lorries and buses, will have to be used for training and testing. Accuracy and equity of the driving exams also need to be enhanced and facilities for taking the driving test in national language need to be developed.

Driver training through driving schools is mandatory before the licensing exam in Bénin, Burkina Faso and Côte d'Ivoire, although number of lessons or duration of the course is not defined or not checked. In driving schools, safety rules and practice are usually not clearly taught. "Informal" training through apprenticeship with another driver exists in all countries, although it is not always officially recognized (as in Côte d'Ivoire); informal training dominates among professional drivers. No
alternative channels are provided to deliver minimum safety knowledge to future users of bicycles (and in some countries light motorcycles) who do not have, by law, to take licensing exams.

Informal driver training appears as a valuable complement to driving schools as it provides practical experience, and it is not to be discarded; on the contrary, it would be useful to facilitate it and provide some accompanying procedures ensuring that new drivers do not learn the mistakes of their masters at the same time as they learn to manage efficiently in real road and traffic conditions.

Development of traffic education for children and young road users is a way to establish sound bases for future driver training and can also provide some of the necessary information to cyclists and moped drivers. Without elaborating here on current traffic education processes in schools in the UEMOA countries, we can stress the need for teaching desirable traffic behaviour through methods adapted to the successive stages of development of the child and the young adult, both in schools and through networks outside schools, as some of the UEMOA countries still display a rather low level of school attendance.

3.4. Road user information

Information of the road users should be useful in the UEMOA countries, particularly to make sure safety regulations and basic rules are known by the public and their purpose and usefulness recognised, also to help improve attitudes of drivers towards the non-motorised road users. In this respect, experience is very similar in the seven countries investigated. Some action is taking place in all of them, with television the media most often used, although radio programmes are also developed, especially as they touch the public of professional drivers. Local radio programmes in national language are considered a valuable complement to national campaigns carried out in French in at least three countries (Bénin, Côte d'Ivoire, Togo).

The problem is that communication with the road users generally suffers from insufficient means to perform long duration information campaigns and evaluate their effects, lack of medium-term planning of campaign themes and targets, heterogeneity of messages leading to an inconsistent image of road safety for the public, and, often, preference of publicity type slogans to a real information content. Some countries however, as Niger and Sénégal, have experimented with longer television programmes; in others, such as Côte d'Ivoire, this is made difficult by the fact that television is commercial and the annual budget for communication would disappear into one single programme.

One further complication in the field of road user information is that private actors, usually associations, sometimes industrial firms or insurance companies, also devote some effort to it, often without proper knowledge of safety or communication methods. Such non-governmental efforts may interfere with messages provided by the (hopefully) more professional public sources. Conversely, they could be made very useful, especially to address specific groups of the population, if they were harnessed to a global coordinated effort at the national level aimed at producing and implementing a consistent information plan through diversified media.

At the national level, some improvements are needed in terms of more regular and adequate funding, partnership, planning and design of campaigns. Information of the road users is also one area where cooperation and exchange of experience between UEMOA countries (and others) may prove the most useful. Some programmes could even be developed on a communal basis.

4. "Corrective" action

4.1. Road safety programmes
None of the UEMOA countries can be said to effectively program safety action at the national level; some annual plans are sometimes produced (for instance by OSER in Côte d'Ivoire), but are only partly applied. The basic tools for programming (accident and traffic data) are currently not easily available, thorough diagnosis of the safety situation is not a regular exercise, coordination of the actors involved is loose, and professionals with actual knowledge of road safety methodology and procedures are scarce.

Without any visible programming effort, safety measures are diluted in other courses of action where they do not get much priority. A preliminary step to developing consistent safety programmes is however to improve the accident data systems and study and diagnosis capabilities (trained teams of professionals and/or scientists) and make intersectoral coordination of decision-making work more efficiently.

4.2. Safety in urban areas

Corrective action is usually not even considered in urban areas, although accidents are frequent and severe as they mostly involve unprotected road users. It can generally be observed that urban roads are under-equipped and in a low maintenance state (carriageway and pavements), facilities for pedestrians are scarce, pavements are used for multiple activities which reduces walking space, access to buses is often unsafe, high speeds are frequent and unchecked, street lighting is low, etc. Reasons for lack of action are technical (lack of local data bases, lack of road safety knowledge among decision-makers and local professionals), institutional (unclear allocation of responsibilities, multiple actors intervening on the same territory), political (safety is not the highest priority of local authorities), financial (city budgets are restricted).

Opportunities for data gathering and for action are opening with the traffic plans that are being developed in the larger cities, through international funding. Safety should normally been taken into account, but some pressure is necessary to ensure that the final plan actually takes into account the needs of unprotected road users, endeavours to regulate speeds through traffic management techniques and the physical design of streets, and provides for adequate safety facilities for all categories of traffic.

4.3. Safety of rural roads

Some countries (Burkina Faso, Niger, Togo) have undertaken blackspot treatment without having access to the correct tools to perform the task (comprehensive accident files including accurate accident locations, detailed accident reports); identification of blackspots is thus perfomed based on the experience of local professionals (police, road engineers) whose subjective assessment is often related more to traffic difficulties or congestion than to actual accident factors. In other countries (Bénin, Côte d'Ivoire), blackspots on intercity roads are identified through analysis of a statistical file of accidents reported by the gendarmerie, but the agencies carrying out the task (for instance, OSER in Côte d'Ivoire) are not institutionally linked to the road administration, and either their proposals get lost in the administrative circuit, or they are not seriously taken into account, or implementation cannot be funded. In fact, there is no provision for safety interventions in road maintenance budgets and any kind of remedial action on roads has to wait for special operations carried out with international funding.

On some of the high traffic routes, infrastructure is now so degraded that blackspot treatment is not the best approach and systematic improvements are needed. Signing and marking are periodically checked in some countries (Côte d'Ivoire, Togo), but are not systematically maintained in others (Bénin, Burkina Faso). Safety devices such as danger signing or guardrails are still scarce in some countries (as Burkina Faso) or have been implemented only on the recently constructed roads (Bénin, Niger). Audits of the state of road maintenance are current procedures in Côte d'Ivoire, Niger, but maintenance budgets have not been up to the task.
Efforts are needed in all UEMOA countries both to upgrade the safety characteristics of the older parts of the road network and to increase and optimise maintenance procedures. On the more recent infrastructures, speeds may be a major problem and require some specific corrective measures, and safety treatment of roadsides seems needed (elimination of obstacles, of differences in level with the carriageway, installation of guardrails along ditches, etc.).

4.4. Care of accident victims

Emergency rescue of accident victims is performed by different actors (ambulances, the fire brigade, gendarmerie, local road users) according to country and location (urban, rural). Communications are not easy on the rural roads, and waiting time between the accident and access of the casualty to a medical centre varies greatly, especially between urban and rural areas.

The Health system in all UEMOA countries works on a network basis, with a hierarchy ranging from Teaching Hospitals (CHU) to the local dispensaries. Accident victims are usually taken to hospital, but, in rural zones, may be brought to a health centre unfit for dealing with emergencies: further transfer may be needed, which delays treatment. Even emergency wards in the better hospitals suffer from limited resources and equipment and from overcrowding. Rehabilitation of recovered victims to reduce permanent disabilities and resulting handicaps seems to be virtually non-existent in the public health sector.

One important issue is that, in some countries, access to medical care is restricted to the fraction of the population getting some form of medical insurance or enough private means to be able to buy medicines and pay the marginal costs charged by hospitals and health centres. Lack of generalised medical coverage leads to (often long) delays at the admission of accident victims (maybe even to refusals, although this is never acknowledged). Moreover, restructuring policies of international donors (such as the World Bank) tend to encourage financial self-sufficiency of public and private medical services, thus raising the costs charged to the patients and accident victims and enlarging the population to whom access to proper care is denied. In such situation, emergency transport of victims becomes a secondary problem.

Some debate is needed on discriminatory access of the population to health centres. Where road injuries are concerned, some solutions could be designed on the basis of a partnership involving the health and transport sectors, law enforcement agencies and the fire brigades, the social security systems as well as insurance companies, so that at least access to hospitals and initial treatment are guaranteed. An evaluation of costs and gains to be expected is needed. Emulation at the regional level could help.

5. Organisation of road safety management

All seven countries investigated have set up some form of institution to coordinate road safety management, with either consultative or decisional or operational powers; all institutions include representatives from relevant non-governmental organisations. Only Bénin displays a dual organisation with a road safety office, CNSR, in charge of studies and of some operational actions, and a Commission for Driving License Withdrawal with enlarged powers in road safety decision-making. Côte d’Ivoire is now setting up a new management system by strengthening the relationships between the national coordinating institution, CNSR, and the road safety office, OSER, that is in charge of support studies and should ultimately assume the permanent secretariat of CNSR.

Road safety management organisations as they have been set up so far meet with similar problems:
a) Although they all exist legally (under different profiles according to countries), the coordinating institutions have too little power to prevail on strongly organised sectors such as road construction and maintenance or enforcement, and get their proposals implemented.

b) Some coordinating institutions (in Côte d'Ivoire, Niger, Togo) are backed up by a secretariat (or a study outfit acting as such) in charge of following up developments between formal meetings and keeping activities going; some of them can even call upon some limited study capabilities (such as OSER in Côte d'Ivoire), but they usually do not have adequate budgets to function (except maybe in Benin where some of the revenues from technical checks of vehicles can be channelized to other areas of road safety work), and even less to fund the studies necessary to support decision-making.

c) Government members of the coordinating institutions are nominated by way of their function in their respective agencies, which means that they change often; as they usually do not have initial knowledge of safety approaches, they have to learn from other members during their mandate and their motivation level may be low. As a consequence, continuity of decision-making is difficult to obtain and road safety experience does not accumulate.

d) Except in Mali, coordinating institutions are not allocated any budget for implementing priority programmes or measures, which means that they must look for outside funding (private, international) or convince their partners to devote part of their own sectoral budgets on the safety measures decided upon. They may not have the authority to succeed (see a)).

In short, attempts at organising intersectoral coordination for road safety management and partnership with NGO’s have been made in all seven countries, but not enough attention has been given to operational requirements, especially to the study capabilities required to prepare and support decisions, and the means devoted to the task have been grossly underestimated. It seems expected that in these countries, road safety management can be organised without spending, which obviously has never been the case in the highly motorised countries where experience with safety management is several decades old. Again, it can be understood that strong political backing will be necessary for road safety management to perform properly, and pressure at the regional level may help national decision-makers and international funding agencies to raise to the challenge.

Although the main contributors to the road safety effort should remain the national and local governments, that are responsible public health, other possible sources of funding for road safety should be discussed with the appropriate partners, especially those in the private sector that should benefit from better transport conditions.

Conclusions

The study carried out for UEMOA provided an opportunity to test an operational methodology for the overall diagnosis of the safety situation at the national level. Although the tool developed can still be improved, it has proved useful in generating comparable information and it can be easily transferred to and used by professionals who are not particularly familiar with road safety management.

The safety problems identified in the seven UEMOA countries investigated are not new and were already detected through earlier studies performed in the 80’s. This shows that little progress has been made in road safety, in spite of the energetic road construction activities going on in some countries (Côte d'Ivoire, for example). In fact, some problems have worsened, as the road maintenance conditions in countries that sustained political and economical problems (Niger), or the emergency treatment of accident victims. There is a case for stating frankly that putting road safety on the agenda goes nowhere if adequate means and organisation are not set up to ensure proper planning and implementation.
Implementation of most of the strategies to reduce accidents and injuries in the long or short term is deeply interwoven with implementation of other government policies and with organisation of the civil society. Road safety policies therefore need to be discussed, argued, and partnerships set up with a variety of administrative or economic actors. None of the problems described in this paper are unsolvable, but none of them can be solved without negotiations in each country and, for some, at the international level. Efficient and highly visible national road safety management systems are a necessary condition for the dynamics to take place. Regional structures providing information and experience exchange, training, facilities for safety studies, guidelines for "good practice" and in charge of harmonization should contribute to the movement and help governments raise the priority of road safety in their own countries.

The findings of the UEMOA study involve seven West African countries which inherited similar administrative systems. Institutional observations may differ in details in other African countries, but one can advance the hypothesis that most of the problems encountered are (or were at some stage) also present there. It would therefore be interesting to include other African countries in the comparison and examine way for making both communities to benefit from each other's experience.

Literature


TRAFFIC SAFETY ON THREE CONTINENTS
Pretoria, 20-22 September 2000

Road Safety Policies in Seven West African Countries

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The following paper is based on work carried out by a team including the authors and F. Châtenet (INRETS), B. Chekarao, M. Fatonzoun (SITRASS), S. Lassarre, J. L’Hoste, F. Piozin, F. Saad, (INRETS) M. Truffier (ISTED), E. Yoro (SITRASS)

ABSTRACT

At the end of 1999, UEMOA, the Economic and Monetary Union for West Africa, launched a study of the road safety situation and management processes in seven countries (Bénin, Burkina Faso, Côte d’Ivoire, Mali, Niger, Sénégal, Togo), in view of formulating safety policies at the Regional level. A team of African and European “experts” was formed to establish a diagnosis on each country, a global assessment of the situation, and draw proposals for action. A provisional report was published in December 1999 and the study will have been finalized by the time the Pretoria Conference takes place.

The team of experts first designed guidelines and a checklist for working out comparable diagnoses at the national level. The issues examined included identification and evaluation of available data and information systems, assessment of the road safety situation as feasible on this basis (numbers and characteristics of accidents, injuries, risk), sectoral and inter-sectoral responsibilities in road safety management, availability of technical support for decisions, partnerships with local actors and with non-governmental bodies, state of development of basic institutions and actions (laws and regulations, driver training and licensing, traffic education, road user information, organisation of professional transport, etc.), remedial measures already applied and implementation processes, and evaluation of past road safety action. Information gathering was carried out through collection and analysis of relevant documents and, mainly, through interviews of a large sample of key-actors in each countries.

The safety diagnoses thus drafted were reviewed and assessed by the team of experts, who drew a global assessment of the road safety management situation in the region and identified common problems. Proposals for action were drafted, covering most of the issues included in the diagnosis, with particular attention to driver training and licensing, enforcement of safety laws and regulations, development of national and regional structures and processes for road safety management, development of accident data collection and management procedures, safety plans for urban areas, safety measures addressing infrastructure and professional transport organization on the inter-urban and inter-State trunk roads, need for specific studies and organization of scientific support. The particular part that UEMOA could play in enhancing road safety in the Region was identified, following three principles: 1) harmonization of standards, laws or procedures when this can prove useful for preventing future injuries; 2) promotion of national safety action through diverse means (sensitization of decision-makers, incentives, technical assistance, training, etc.); and 3) providing common resources (funds, knowledge, manpower, safety material, etc.). The proposals are being reviewed by UEMOA and a final report and conclusions should be available by April 2000.
The UEMOA study provided an opportunity to develop and check working procedures to assess road safety management at the national level at the same time as it sought to achieve its main goal: to provide strong and objective support for decision-making at the Regional level.

High risk zones, high risk conditions
Daniel Heuchenne

Light condition and safety on highways
Annie Canel

Zero fatalities – is that possible?
Trygve Solheim

Global standardisation – redefining
Stefan Lötter

An investigation of traffic crash migration at urban intersections
Tapan Datta
TRAFFIC SAFETY ON THREE CONTINENTS
PRETORIA - SEPTEMBER 2000

THEME 3: TRAFFIC SAFETY POLICY, TRAFFIC SAFETY PROGRAMMES
HIGH RISK ZONES, HIGH RISK CONDITIONS

Daniel HEUCHENNE
Ministry of Equipment and Transport
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ABSTRACT

As far as road safety is concerned, the Walloon Region of Belgium has concentrated its action on two fields: the road network and the drivers’ behaviour.

The road network

High-risk sites are detected by means of an automatic method for searching accident concentrations that is an extended concept of black spots. Once located, each of these sites will be submitted to a multi-criteria analysis taking account of the number of victims, geometry, traffic and the frontage residents’ density. Each of these sites then receives a global mark indicating the importance of an intervention. The sites concerned are classified annually according to this mark and the selected sites are analysed from the accidents’ point of view. An efficiency comparison is then carried on and finally a confrontation with the knowledge of the physical field of local authorities and local road managers. This five steps approach guarantees the selection of the sites that will offer the greatest social benefit and the optimisation of public money. It should progressively lead to an optimum network.

The drivers’ behaviour

The aim of the study is to determine the most frequent mechanical and sociological causes of injury road accidents in order to take the most efficient political measures. An accident is generally due to the conjunction of several factors. Each combination of sociological and mechanical factors defines an accident sequence. The most frequent sequences thus must be specified in order to know: 1) the mechanical causes (slippery bend…) and 2) the targets (for instance: young unmarried drivers). This will allow the definition of road safety strategies.

Two complementary databases are available: the forms filled in by the gendarmes or police officers after an accident and the national survey on household mobility carried out in 1999. Both of these data sources have variables in common (such as, for instance, age, gender, transport mode), which allows cross-checking.

A first analysis is being done on the factors and a second one will concern the combination of factors or accident sequences. That way, it will be possible in the years to come to take actions aiming at modifying the drivers’ behaviour, such as training and education at school, retraining courses for high-risk drivers, probationary periods for elderly drivers, campaign against alcohol abuse.
HIGH RISK ZONES, HIGH RISK CONDITIONS

1 INTRODUCTION

In South Belgium, a calculation concerning 9,000 km of the national network showed that the complete normalisation of the network (that is to say a thorough treatment of all the dangerous zones) would mean 25% less victims (dead within thirty days and seriously injured). The accidents due to vehicle failure are not numerous thanks to the vehicle checking which is compulsory from the fourth year onwards. The same applies to the combination of unavoidable circumstances. So it seems that nearly 75% of the victims are attributable to inadequate driving behaviour.

In consequence, South Belgium will go up to two fronts: black sites and driver behaviour in certain conditions.

2 INDICATORS

In South Belgium, roads constitute the first mortality factor - when counting the number of potential life years lost [1] - and come before suicide and ischemic heart diseases, and this because young people are mostly involved. It is a national problem requiring national budgets. The public health point of view therefore prevails and following indicators seem to be the most interesting:

- The number of dead equivalents (dead within thirty days + seriously injured multiplied by a coefficient of equivalency)
- The number of potential life years lost up to the age of 70 (dead + seriously injured multiplied by a coefficient of equivalency)

At the present time, we use the value of 0.20 for the coefficient of equivalency because it is the most common ratio between the economic costs of a dead and a seriously injured person but a research is being done to replace it by the mean ratio of handicap. After having investigated all the available international scales of handicap, the FIM-FAM scale has been chosen; it means "Functional Independance Measure and Functional Assessment Measure. Now we are doing statistics to know the mean value.

This last indicator allows to introduce a "quantity of life" parameter at the same time as a "quality of life" parameter in government criteria.
3 THE ROAD NETWORK: HIGH RISK ZONES

The first level

When we have a look at the network, various concentrations of accidents appear here and there, especially at crossroads, cross-town links and other dangerous sites. Up to now, we considered there was a black spot where three accidents with casualties occurred during the same year on the same hectometre. But this method was too much focused on specific points. Indeed, if these three accidents are spread over 4 or 5 hundred meters, in the case a crossroads for example, the site won't be considered as a black site. Nevertheless, this crossroads is responsible for the accidents. We therefore established a black zones method which also takes account of the accidents in the four neighbouring hectometres - two at the entrance and two at the exit of the crossroads concerned - but with a weighting coefficient decreasing with the distance. We did the same with time: if we study a month, we include the accidents which occurred during the five preceding months and the five following months by using a parabolic decreasing coefficient.

Finally, an average of these values over a span of five years is made in order to determine the dangerous zones. This average will be called "safety index". When it will be higher than 2.4, which corresponds roughly to the former conception of a black spot - that is to say 3 accidents a year ON THE SAME SITE - the hectometre will be qualified as a "high-risk site". When the index is situated between 1.2 and 2.4, the hectometre will be considered as a "medium-risk site". In 1994, the Region presented 200 High Risk Sites and 1000 Medium Risk Sites and these sites contained 26 per cent of the accidents with casualties.

THE DEAD AND THE LOST YEARS OF LIFE IN SOUTH BELGIUM / 1990-93

<table>
<thead>
<tr>
<th>CAUSES OF THE DEATH</th>
<th>LOST YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicles accidents</td>
<td>7.34</td>
</tr>
<tr>
<td>Suicides</td>
<td>5.72</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>4.32</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>3.63</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>3.59</td>
</tr>
<tr>
<td>Respiratory infection</td>
<td>2.50</td>
</tr>
<tr>
<td>High blood pressure and cerebrovascular diseases</td>
<td>2.19</td>
</tr>
<tr>
<td>Cirrhosis</td>
<td>1.92</td>
</tr>
<tr>
<td>Neck of the womb cancer</td>
<td>0.35</td>
</tr>
<tr>
<td>Other causes</td>
<td>24.19</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>55.75</strong></td>
</tr>
</tbody>
</table>
The second level

If the first stage was to localise these sites on the map thanks to the safety index, the second consisted in analysing everyone of them with a multicriteria grid. That way, a set of indicators was added in order to draw up an assessment grid that gives an overview of the situation from the standpoints of both safety and mobility. This approach will allow us to better define the real risk of accidents.

The safety criterion is based on two accident indicators, on two spatial indicators and two traffic-related indicators. In addition, the movement of parking vehicles and pedestrians is specified by two other indicators: the number of dwellings and public buildings. At the beginning, we also considered using mobility indicators but now safety became so important that only the safety criterion has been retained. At the bottom of the grid, a global figure can be calculated, but it will never replace the grid. When converted into a bar graph, this grid gives a picture of all the components of a site and enables to take in its qualities and flaws at a glance. Several sites can be compared by lining up all the bar graphs. This method allows us to make choices and to establish a list of improvement works classified according to decreasing priority.

The third level

This stage is to analyse the accidents on the site and to set up the corresponding improvements. As an example, a high number of turn-on-the-left accidents will result in turn-on-the-left lanes or a roundabout etc.

The fourth level

Now we need to calculate the benefit – in dead-equivalents or in lost years of life – of every project of worksite, and more specifically the benefit for one million invested. This is named “efficiency” of the improvement. A new ranking will be pointed out on the efficiency basis.

The problem is to know the efficiency of every type of improvement: delineator posts, carriageway markings, roundabouts... Here we have no specific studies in our country and we are obliged to take them abroad when waiting to have our own studies. Then we have consulted the driver’s behaviour diagrams of the SARTRE [2] study that has compared the behaviour in the 15 countries of Western Europe to find that Spain was always very close to Belgium. We thus have retained the Spanish Tables published by Elsamex in 1996 [3].
Fifth level

The last approach is to compare these theoretical considerations with the field. We held a meeting
with the chief-engineers of every province: they physically know their road network and can tell
"Attention, here there will be a new big market next year, the traffic will increase and this crossroads
will be overloaded, new accidents will appear, this calls a higher priority…"

Finally

So, the complete study of a site is carried out at five levels: the safety index, the multicriteria grid, the
accident analysis, the efficiency of improvements and the confrontation with the physical field. It allows
to set up a ranked listing of the risk sites so that political authorities can choose every year the sites to
fit up, drawing the maximum profit of public money. This approach allowed us to reduce the number of
High Risk Sites from 200 to 80 in 4 years and to lower the number of victims (killed and seriously
injured people) by 21% and this, despite a 9% increase in the number of vehicle kilometres!

4 THE DRIVER: HIGH RISK CONDITIONS

The aim of this study is to determine the most frequent mechanical and sociological causes of
casualty road accidents in order to take the most efficient political measures.

An accident generally is the result of a group of factors. For instance: <an unmarried young driver (1)
enters a slippery (2) bend (3) one Saturday night (4) > is a combination of 4 factors. The factor (1) is
sociological and the others are mechanical. Each combination of sociological and mechanical factors
defines a type of accident. The most frequent types must therefore be specified in order to know: 1.
the targets (for instance, young unmarried drivers of a given socio-economic class) and 2. the
mechanical causes (slippery bend…). This will allow the definition of strategies such as signing,
advertising and training campaigns and others in order to change the drivers' behaviour, as well as the
determination of possible improvements.

Accident sequences can be deduced from two sources: 1. the forms filled in by the gendarmes or
police officers after an accident and 2. the national survey on household mobility as far as accidents
are concerned. These two databases are complementary. The first one is an exhaustive database
comprising about 45,000 accidents recorded over three years and counting 60 variables The second
one is a sociological accident database, based on the declarations of persons polled on mobility in
general. Several hundred accidents distributed over thousands of individuals for whom several
hundred variables are defined will thus be available. Both of these data sources have variables in
common (such as, for instance, age, gender, transport mode, etc) thanks to which it will be possible to
define classes of individuals common to both databases and thus to have a basis for comparing data.

The correspondence factor analysis

A classical CFA will point out the most frequent factors that are at the origin of the accidents.

The sequential analysis

This analysis is based on the principles applied by Dawn and Massie [4] and the Belgian Road Safety
Institute (IBSR) [5] and aims at determining the most frequent accident sequences. It identifies the
most frequent 'groups of factors' using the following approaches:

1. classification tree (CART segmentation)
2. neural network
3. hierarchical clustering (CAH)
4. partitioning par nuées dynamiques
5. factorial correspondence analysis
6. projection pursuit regression (contrasting FCA)

That way, it will be possible in the years to come to take actions aiming at modifying the drivers' behaviour, such as training and education at school, retraining courses for high-risk drivers, probationary periods for elderly drivers, campaign against alcohol abuse, etc.

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ABSTRACT

Statistical records show that nighttime accidents are usually more numerous and serious than daytime accidents. These observations have lead several experts and professionals to suggest increasing lighting and providing a similar environment to daylight conditions through continuous lighting. Experimental studies, funded by the French Ministry of Transportation, were conducted to investigate the effects of light conditions on drivers’ behavior. Experiments were carried out by the Laboratory of Applied Anthropology, Paris University of Medicine, in real driving conditions on Belgian and French highways. They mainly compared drivers’ behavior in continuous lighting condition and in no-continuous lighting condition. Occurrences of microsleep and hypovigilance were analyzed for each driver. This study suggested that continuous lighting conditions would not necessarily improve vigilance. Moreover, it was found that, on long runs, safety could be worsened under continuous lighting, as the elapsed time between hypovigilance occurrences would tend to decrease. This study demonstrated that increasing lighting and trying to create a similar environment to that of daytime situation might not improve night traffic safety. It also highlighted that drivers’ behavior should be taken into account to better identify the amount and type of public lighting that would be required to perform driving tasks adequately. Results also indicate that efficient countermeasures should break monotony, or make a more appropriate use of rest areas. Significant advances have been achieved in the knowledge of driver’s behavior at night; but more research is needed in the field of night traffic studies.

INTRODUCTION
Statistical records from the French Agency for Road Safety show that nighttime accidents are usually more numerous and serious than daytime accidents. In 1999, it was estimated that 257 people were killed and a further 591 were seriously injured in night traffic accidents on French highways. During the same year, 217 fatal accidents were recorded - as compared to 184 daytime fatal accidents - while the total number of nighttime accidents (2641) was smaller than that of daytime accidents (4162). Data also show that more people were killed in night accidents (257) than in daytime accidents (208); a much higher number of fatal accidents occurred in dark unlit situations than on lighted road sections (3 to 4 times greater); the same is true for the number of fatalities. Similar trends were reported for 1995, 1996, 1997 and 1998.

These observations have lead several experts and professionals to suggest increasing lighting and providing a similar environment to daylight conditions through continuous lighting. Others have pointed out that there was no evidence that lighting would improve safety and warned against the risk for sleepiness under monotonous driving conditions.

Two experimental studies, funded by the French Ministry of Transportation, were conducted to investigate the effects of light conditions on drivers’ behavior. Experiments were carried out on Belgian highways (for the continuous lighting conditions) by the Laboratory of Applied Anthropology, Paris University of Medicine. The studies were based on an objective approach in real driving conditions. The first study was performed during the winter of 1998, under poor weather conditions. In order to eliminate the effects of those meteorological conditions on drivers’ vigilance, a second study was carried out during the spring of 2000, under more favorable weather conditions. One major issue raised in the study concerned the efficacy of continuous lighting as sleepiness countermeasure. To this purpose, data, such as microsleep duration and hypovigilance periods, were recorded. Comparisons with drivers’ subjective estimates allowed to evaluate the risk taken by drivers under continuous lighting. The results of these studies were compared to those of a previous study conducted on French highways (with no-continuous lighting conditions) using a similar study protocol.

**METHODS**

**Participants**

A sample of 8 professional male drivers (ages 23 to 45) participated in day and night trips in the 1998 experiments; 4 of them also participated in the experiments carried out in 2000. All of them had a “usual” sleep time during the night before the experimental trip, except one of them who had a slight sleep debt. All drivers could rest in a hotel before the night trip. Most of them slept during 30 minutes to 1 hour ½. Subjective estimates of sleepiness and fatigue of each driver were assessed. Only one of them felt drowsy when he started driving.

**Experimental Design**

A Peugeot 806 vehicle was instrumented by the Paris Rhin Rhône Highway Company to carry out the experiments. The electrophysiological signals, i.e electroencephalogram (EEG) and electrooculogram (EOG), were monitored. Driver’s face and eye movements, as well as forward highway view were monitored by 2 video-cameras. The inside temperature was kept between 20°C and 24°C according to the driver’s request. Constant speed was required
around 120km/h. Listening to radios was not allowed. Oral communications were reduced to a minimum during the drives. Two experimenters were present in the vehicle, one for observations and coding of driving tasks, and one for checking the records.

Each participant completed two driving runs. Each driving run consisted in one day drive and one night drive; each drive took place from Lille, France (at the French/Belgian border) to Liège, Belgium, and back to Lille. The daytime drive took place from 13.00 to 18.00 and the night drive took place from midnight to 5.00. An interval of 2 weeks separated the two replications. In the second replication the protocol was the same as during the first replication. The driving distance was about 320 km.

Drivers were allowed to stop and take a break when they felt tired. 10- to 20-min naps were allowed during the night breaks. The experimenter had to request the driver to stop for a break when he estimated that the driver was not able to drive safely.

**Table 1 – Experimental protocol for a driving run (including one day drive and one night drive)**

<table>
<thead>
<tr>
<th>Time</th>
<th>Experimental activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 9.30</td>
<td>Sleep diary for the week prior to experimental drives.</td>
</tr>
<tr>
<td>9.30 - 11.30</td>
<td>Vehicle equipment testing.</td>
</tr>
<tr>
<td>11.30 – 12.30</td>
<td>Lunch</td>
</tr>
<tr>
<td>12.30 – 13.00</td>
<td>Placement of electrodes.</td>
</tr>
<tr>
<td>13.10 – 18.00</td>
<td>Day drive. The driver stops driving when necessary. At least one 20-min break is required at half distance.</td>
</tr>
<tr>
<td>18.00 – 18.30</td>
<td>Removal of electrodes. Completion of sleepiness/fatigue questionnaire and interview of the driver.</td>
</tr>
<tr>
<td>18.30 – 19.30</td>
<td>Record saving and checking.</td>
</tr>
<tr>
<td>18.30 – 23.30</td>
<td>Break including dinner and nap in a hotel room.</td>
</tr>
<tr>
<td>23.00 – 23.30</td>
<td>Vehicle equipment testing.</td>
</tr>
<tr>
<td>23.30 – 24.00</td>
<td>Placement of electrodes.</td>
</tr>
<tr>
<td>24.00 – 5.00</td>
<td>Night drive. One 20- to 30-min break is required. The driver is allowed to sleep 20 min maximum.</td>
</tr>
<tr>
<td>5.00 – 5.30</td>
<td>Removal of electrodes. Completion of sleepiness/fatigue questionnaire and interview of the driver.</td>
</tr>
<tr>
<td></td>
<td>Record saving and checking.</td>
</tr>
<tr>
<td></td>
<td>End of experiment.</td>
</tr>
<tr>
<td></td>
<td>A room is provided to the driver for sleep.</td>
</tr>
</tbody>
</table>

**Performance measurement**

During each drive, the following data were collected:

1. On the driver:
   - Electroencephalogram (EEG)
   - Electrooculogram (EOG)
   - Electrocardiogram (ECG)
   - Face movements
   - Subjective estimates by drivers of their degree of fatigue, sleepiness, difficulty.

2. On the vehicle:
   - Speed
   - Lateral lane position
3. On the environment:
   - Forward highway view
   - Time recording of driver’s tasks, driving phases, communications … using a pre-established model.

Hypovigilance and microsleep times were especially checked. They were identified for each driving run using an analysis of both electroencephalogram and electrooculogram parameters. Hypovigilance stages are characterized by EEG alpha activity (8 – 12 Hz). They occur during the night as well as during the day, when subjects are placed in monotonous conditions with little stimulation, even when no sleep debt is reported. This is to be compared with EEG for normal alertness in the range 13 and 30 Hz. Microsleep stages are defined by EEG theta activity (3 – 7 Hz). They are associated with sleep debt. Duration of microsleep varies from 1 to 8 s. They are a major factor influencing accident risk. They are also associated with slow ocular movements (EOG), which reduce signal perception dramatically.

Data analyses focused on the duration of hypovigilance and microsleep as related to the driving sessions and the continuous lighting of the Belgian highways. Data previously obtained on French highways (1996) with no-continuous lighting were used as a reference to evaluate the effects of continuous lighting on drivers’ behavior.

RESULTS

Recorded data

- Naps and breaks

Generally, duration of day and night breaks was similar on Belgian and French highways, i.e. in continuous and no-continuous lighting conditions. A significant difference was observed with duration of breaks in the 1998 study in the continuous lighting / poor weather conditions, especially with the first break. The higher duration was most likely due to the detrimental influence of poor weather conditions, but also to more comfortable resting conditions whose effect on duration of breaks and naps was confirmed.

- Hypovigilance and microsleep

Total duration of hypovigilance and microsleep was calculated for the first three night driving hours. Most generally, total hypovigilance time was higher in the continuous lighting condition than in the no-continuous lighting condition. As for microsleep, no clear conclusion could be made. Results revealed once more strong differences between individuals, on the contrary to hypovigilance which highly depends on monotonous conditions. Microsleep was more likely to be found in the no-continuous lighting condition whereas hypovigilance was more frequent in the continuous lighting case. However, no significant differences were observed. The results suggested that reducing drowsyness was more likely to be achieved through sleep quality and appropriate amount of sleep prior to departure than through lighting. Also, monotonous conditions seemed to be an influencing factor. Yet, specifically on
long driving runs, the findings indicated that continuous lighting was likely to induce monotony.

![Chart showing duration of hypovigilance and microsleep](image)

**Figure 2:** Tests on French and Belgian highways
Mean total duration of hypovigilance periods during the 3 first driving hours.

- **Hypovigilance and microsleep re-occurrence time**

As for hypovigilance, re-occurrence time of the first cluster of hypovigilance periods after the first break was considered. For microsleep, re-occurrence time of the first microsleep in a cluster of microsleep periods was recorded. During daytime runs, results showed similar hypovigilance re-occurrence times in continuous lighting conditions as in no-continuous lighting conditions. During nighttime runs, hypovigilance re-occurrence times were higher in continuous lighting / favorable weather condition and lower in no-continuous lighting condition. Microsleep re-occurrence times were the lowest in continuous lighting / favorable weather conditions. However, it is important to note that they remained higher than those observed when participants had no sleep before departure. The result confirmed the negative influence of sleep debt and the importance of allowing some sleep prior to departure to significantly improve the benefits of breaks.

To summarize, total duration of hypovigilance and microsleep were similar in continuous lighting and no-continuous lighting conditions while hypovigilance and microsleep re-occurrence times were lower in continuous lighting / favorable weather conditions. These findings indicate no clear effects of continuous lighting as countermeasure to sleepiness on long driving runs.
- **Subjective estimations**

Each participant estimated her or his sleepiness and fatigue degrees at several points during each run using analog scales. They were also asked to estimate the difficulty or easiness to drive.

Generally, results showed similar increasing trends for sleepiness and fatigue degrees in different lighting conditions, during nighttime and daytime trips.

Different results were observed on difficulty/easiness estimates. During daytime runs as well as during nighttime runs in continuous lighting conditions, a decreasing difficulty associated with a feeling of higher alertness was observed at the end of each run. This self-evaluation was not confirmed by experimental data which generally showed increasing efforts made by the drivers. The gap with experimental data was at its highest in this case.
Figure 4: Subjective evaluations of sleepiness, fatigue and difficulty during nighttime drives on Belgian and French highways.
DISCUSSION

The study protocol was intended to induce monotonous driving and drowsiness by combining constant speed, restrictions on radio listening and limited oral communications. Generally, the protocol was successful. However, during the first experimental campaign (1998), because of unfavorable weather conditions, the protocol was changed in order to maintain safety conditions. Unfortunately, it was not possible to evaluate the effects of these conditions on participants' vigilance/sleepiness, since on the one hand bad weather was a stimulating factor and on the other hand it significantly hastened the onset of fatigue. Most participants, because of difficult conditions, required more rest and naps. Driving distances were reduced, and more breaks were allowed. In such conditions, the analysis could not identify the effects of continuous lighting on drivers' vigilance. However, an incomplete result of this first experimental campaign showed that, contrary to general belief, continuous lighting did not maintain alertness on long runs in poor weather conditions.

One major issue addressed in the analysis concerned the effects of continuous lighting on driving performance. The study was intended to discuss two related arguments, the first about using continuous lighting on highways, and the second about alternate solutions. No conclusion could be reached as for the effects of continuous lighting as an effective countermeasure to combating sleepiness. Specifically, the total microsleep and hypovigilance times were similar in this study as had been observed in a previous study involving driving runs with no-continuous lighting. Also the observed microsleep and hypovigilance reoccurrence times, which decreased with long driving times, did not indicate a positive influence of continuous lighting on drivers' alertness. Appropriate alertness was maintained until the first break in all conditions; hypovigilance and microsleep re-occurred after short periods of time in continuous lighting conditions.

Contrary to experimental data, subjective estimates showed significant influence on drivers' behavior. They indicated positive benefits associated with continuous lighting in terms of environment perception and driving comfort. Of particular interest is the gap that was observed between experimental and subjective results, which was at its highest with continuous lighting and favorable weather conditions. The gap clearly appeared on assessed difficulty even more than on fatigue and sleepiness. Subjects did not consider driving as a difficult task on continuous lighted highways, especially in good weather conditions, while they mentioned a different opinion on French unlighted highways. However, in both cases, they felt tired and somnolent. This result suggested that continuous lighting might not have beneficial effects on safety, since drivers may delay breaks and continue driving beyond the point at which they should have stopped. These findings indicated that continuous lighting, in comfortable driving conditions, may increase accident risk.

Lighting has usually been considered a way to reproducing daytime conditions during the night. Accordingly, continuous lighting was seen as a relevant solution. Such a solution did not take into account drivers' behavior and real night traffic. It was based on general opinion that there were no major difference between drivers' behavior at night and during the day, or at least that they can be strongly reduced, and that differences between night and day traffic only related to quantity of vehicles.

Yet, numerous studies have described subjects' behavior at night. Circadian factors are a major factor influencing driver's fatigue, and sleepiness is more difficult to resist at night than during the day. Moreover, microsleep is more likely to occur at night than during the day, as
shown in the present study. Also, there is general agreement that microsleep is due to sleep deprivation and that naps may be the only effective countermeasure in that case. The findings of the present study are consistent with those results, as they indicate that continuous lighting does not reduce microsleep. In summary, continuous lighting does not compensate for microsleep and circadian factors. To this point, the results also show, as observed in previous studies, that sleep prior to driving is the most effective countermeasure. As for hypovigilance, which is due to monotonous environment, lighting might be of some help. However, the results suggest that continuous lighting should be more preferably used on short distances than for long duration trips.

Lighting should be seen as a means among others, such as signs and marking, to stimulate alertness and not as a way to reproduce daytime conditions. In this perspective, continuous lighting may be a relevant solution, still to improve and to adapt, in urban and suburban areas, where heterogeneous environment involves numerous obstacles and complex information to process. In rural areas, lighting of specific places and dangerous points, may be helpful to perform driving tasks at night, create contrasting settings and stimulate driver’s attention.

The study also showed major behavioral differences between subjects. The results suggest that each driver should be aware of her or his ability to drive safely at night or in the morning and adapt her or his driving habits accordingly. Also, drivers should consider themselves and should be educated as actors instead of potential victims. Whatever improvements are being made to highway lighting systems over the next years, driver involvement will be crucial.

Significant advances have been achieved in the knowledge of driver’s behavior at night. Such progress definitely allows improvements in road safety. Nevertheless, no strong conclusion can be reached as for effective lighting systems or alternate solution to combating drowsiness. This would require more research in the field of night traffic studies.
ACKNOWLEDGEMENTS

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REFERENCES

Implementing traffic safety measures

Zero fatalities – is that possible

By Trygve Solheim
Senior research officer
Institute of transport economics (TØI)
Oslo, Norway

Introduction

Measures to improve traffic safety is easier to implement when introduced as part of a larger road-infrastructure program. Safety measures that demand significant investments and that reduces traffic speed are more difficult to implement than others. This may seem obvious, but is important for a realistic view of what is possible when working with traffic safety. Too often planners and politicians focus on paper tigers, good plans with no power base, or white elephants, poor plans with a strong power base, or a large potential for working as a symbol for little or nothing happening.

In the autumn of 1998 The National Swedish Road Administration (Vägverket) gave TØI the task of analysing which measures for improving traffic safety conditions that was possible to implement, considering economic, political, social, organisational and cultural conditions in the Swedish (and Norwegian) society. The result of the project is presented in this paper. The conclusions is mainly in the type of thoughts, not straight and underlined answers. The results are hypotheses, based on theories about decision-making processes and to some extent, facts gathered from examples of such processes. I have experienced, over the last years, that too few studies have been conducted into the world of power and politics around road-building and traffic-safety. The main focus has been on effects of measures, not processes concerning how they did or did not come into being.

Measures that have effect

In the project we picked six groups of measures. The choices were based on expected effect, type of measure, geographical fit, degree of conflict related to the measure and whether the measure was seen as easy or difficult to implement:

- Measures in the road network; larger road-projects and conflict-checking measures.
- Measures to reduce speed in sparsely populated areas; speed-limits, police controls, automatic speed controls (ATK).
SUSTAINABLE TRAFFIC SAFETY
“From a corrective to a preventive approach”

Jos Spriel
1. Introduction
For a long time, traffic safety policy in and outside the Netherlands has been based on corrective measures. Road sections and intersections with the most accidents (black spots) received the highest priority in improvement programmes, and groups of road users most frequently involved in accidents were the focus for information campaigns.

Early in the 1990s, improvements in traffic safety seemed to come to a standstill. General and political interest in traffic safety diminished, and a new impulse was necessary. This turned out to be an intention to achieve sustainable safe traffic and transport systems, based on a preventive approach, which focused full attention again on the three old traffic components of people, vehicles and infrastructure. However, the approach was integrated this time and these aspects were handled together, not separately.

A sustainable safe traffic system includes [ref. 1]:
✓ an infrastructure whose design is adapted to the limitations of human capabilities,
✓ vehicles equipped to facilitate human tasks and constructed so as to optimally protect people, vulnerable as they are, and
✓ traffic participants who are adequately educated, informed and, where necessary, monitored.

2. Infrastructure
It would be impossible to briefly summarise all the proposals and measures covering the three components of traffic safety: people, vehicles and roads. For more information see the presentation of the Dutch Ministry of Transport [ref. 2]. At CROW, we concentrate mainly on the roads (design, layout and environment), which is why the consequences of the Sustainable Traffic Safety philosophy for this component will be discussed in more detail in this text – naturally, in relation to the other two components.

It is essential to harmonise the function, design and use of roads, when considering their arrangement and layout. For this, it is important to establish the function of roads in the road system. This will enable the proper design and layout to be chosen. When design is well-attuned to function, roads will be used by traffic participants as intended. Examples are motorways for high-speed car traffic over (medium) long distances and residential streets for reaching residences by all sorts of traffic.

In addition, a sustainable safe infrastructure is based on three essential safety principles [ref. 3]:
1. functional use – prevention of incorrect road use, e.g. traffic taking short cuts;
2. homogenous use – prevention of big differences in speed, direction and volume at moderate speeds (50 and 70 km/h) and high speeds (80 km/h and higher);
3. predictable use – prevention of uncertain behaviour by road users.
3. Road categories

Keeping in mind these three principles, a CROW working group has developed a system for categorising existing and future road systems. An approach has been used as the basis for this with three development steps, as follows:
1. functional criteria for the system;
2. operational criteria for road categories;
3. design criteria for every category (for road sections and intersections).

3.1 Step 1: functional criteria

To be able to safely classify the road system, a restricted number of road categories must be permitted [ref. 3]. Safety principles and experience in various experiments show that there are two safe road categories. Firstly, there are roads designed for high-speed flows of (chiefly motorised) traffic, opposing traffic flows of which are fully separated. Crossings are on a different level and interchange of vehicles is achieved by merging on and off. Secondly, there are roads that offer access exclusively to residences, rarely used by through traffic, if at all. On these roads, all users drive in the same lane, and intersections and crossings occur at street level and at any desired point.

We call these two categories, respectively: through roads and access roads.

In addition, an intermediate term is necessary to suit the area between these two extremes. This type of road is intended to open up areas, which is why they are called distributor roads.

When two sorts of traffic movements are discussed, interchanging and through traffic, the three road categories can be characterised as follows:

<table>
<thead>
<tr>
<th>road category</th>
<th>interchanging traffic</th>
<th>through traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>through road</td>
<td>on road sections and intersections</td>
<td></td>
</tr>
<tr>
<td>distributor road</td>
<td>on intersections</td>
<td>on road sections</td>
</tr>
<tr>
<td>access road</td>
<td>on road sections and intersections</td>
<td></td>
</tr>
</tbody>
</table>

Basically, functional requirements apply to roads both in and outside built-up areas. But, in view of the function of through traffic, it is unlikely that it can be applied in built-up areas. In the rare event that a through road is found in built-up areas, the same requirements would apply as to through roads outside built-up areas.

In addition to the three road categories, twelve functional requirements can be derived from the three safety principles for a sustainable safe road system:
1. Creating connected residential areas that are as large as possible.
2. Reducing driving on relatively unsafe roads as much as possible.
3. Keeping rides as short as possible.
4. Having the shortest and safest routes converge.
5. Avoiding search behaviour.
7. Limiting the number of traffic solutions and making them uniform.
8. Avoiding conflicts with oncoming traffic.
9. Avoiding conflicts with cross traffic.
10. Separating types of vehicles.
11. Reducing speed at potential points of conflict.
12. Avoiding obstacles along the carriageway.
The first four are requirements that can be set for a road system. The next three are applicable to routes. For road sections, numbers 6 and 7 as well as 8 to 12 are important. Requirements 5 to 12 are for intersections.

The above requirements are more or less applicable to all sorts of road users. That is why it is important for every type of user to develop a notion of what is desired on the basis of these 12 requirements. These road concepts then have to be compiled and attuned, resulting in a functional road system.

3.2 Step 2: operational criteria

It is then essential to formulate operational requirements for the three road categories. These operational requirements are specifically intended to clarify the differences between the categories for users. In a sustainable safe traffic system, all users are aware at all times of the type of road they are on and know what is expected of them. The following design elements are considered in operational criteria:

- statutory maximum speed limit
- signs
- *longitudinal road markings*
- *carriageway design*
- colour and texture of pavement
- *woonerf connections*
- *carriageway separation*
- crossing on road sections
- parking
- public transport stops
- *provisions for breakdowns*
- obstacle distances
- bicycles
- mopeds
- slow-moving motorised traffic
- speed control measures
- lighting
- *intersection principles*
- transition of road category

From a comprehensive study conducted by TNO and SWOV on various groups of road users, design elements were taken that road users base their behaviour on and consequently use to make a distinction between the various road categories. These design elements are called essential characteristics and are marked above in italics.
Operational requirements for each road category have been identified for these operational criteria. Separate tables have been developed for intersection and crossing designs. Other operational requirements have been formulated for roads outside built-up areas as follows:

<table>
<thead>
<tr>
<th>Operational criteria/design elements</th>
<th>Operational requirements (outside built-up areas)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>through roads</td>
</tr>
<tr>
<td>maximum speed</td>
<td>120/100 km/h</td>
</tr>
<tr>
<td>signs</td>
<td></td>
</tr>
<tr>
<td><strong>longitudinal road markings</strong></td>
<td>fully</td>
</tr>
<tr>
<td><strong>carriageway design</strong></td>
<td>2 x 1 or more</td>
</tr>
<tr>
<td>colour and texture of pavement</td>
<td>impervious (asphalt or concrete)</td>
</tr>
<tr>
<td>woonerf connection</td>
<td>no</td>
</tr>
<tr>
<td><strong>carriageway separation</strong></td>
<td>hard</td>
</tr>
<tr>
<td>crossing road sections</td>
<td>different level</td>
</tr>
<tr>
<td>parking</td>
<td>no</td>
</tr>
<tr>
<td><strong>provisions for breakdowns</strong></td>
<td>emergency lane</td>
</tr>
<tr>
<td>obstacle distance</td>
<td>large</td>
</tr>
<tr>
<td>bicyclists</td>
<td>separated</td>
</tr>
<tr>
<td>mopeds</td>
<td>separated</td>
</tr>
<tr>
<td>slow-moving motorised traffic</td>
<td>separated</td>
</tr>
<tr>
<td>speed control measures</td>
<td>no</td>
</tr>
<tr>
<td>lighting</td>
<td></td>
</tr>
</tbody>
</table>
As previously stated, operational requirements have been formulated for the various intersections. This takes account of all unusual routes such as cycle tracks, bus lanes and underground infrastructures. For roads outside built-up areas, the table is as follows:

<table>
<thead>
<tr>
<th>Operational requirements for intersections outside built-up areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>road category</td>
</tr>
<tr>
<td>through roads</td>
</tr>
<tr>
<td>distributor roads</td>
</tr>
<tr>
<td>access roads</td>
</tr>
<tr>
<td>bicycle tracks</td>
</tr>
<tr>
<td>public transport lanes</td>
</tr>
</tbody>
</table>

A similar table has been formulated for transition areas. In some cases, it concerns built-up area boundaries, while in others it involves the transition from one category to another. The table shows which transitions are allowed (or acceptable from the standpoint of traffic safety).

<table>
<thead>
<tr>
<th>transition</th>
<th>through road</th>
<th>distributor road o.b.a.</th>
<th>access road o.b.a.</th>
<th>distributor road i.b.a.</th>
</tr>
</thead>
<tbody>
<tr>
<td>distributor road o.b.a.</td>
<td>intersection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>access road o.b.a.</td>
<td>unacceptable</td>
<td>intersection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>distributor road i.b.a.</td>
<td>unacceptable</td>
<td>area boundary or intersection</td>
<td>area boundary or intersection</td>
<td></td>
</tr>
<tr>
<td>access road i.b.a.</td>
<td>unacceptable</td>
<td>area boundary and/or intersection</td>
<td>area boundary or intersection</td>
<td>intersection</td>
</tr>
</tbody>
</table>

o.b.a. = outside built-up areas
i.b.a. = inside built-up areas

These are the functional and operational requirements.

3.3 Step 3: design criteria
Design requirements can be developed on the basis of the functional and operational requirements for sustainable safe roads, which are formulated on the basis of design elements as mentioned in the operational requirements. As this concerns a totally new approach to road design, the design requirements are provisionally referred to as “recommendations”. At a later stage, when these recommendations are put into actual practice and evaluation results are known, they may be changed into design requirements. A distinction is made in design recommendations between roads inside and outside built-up areas. First, recommendations are discussed for roads outside built-up areas, then for area boundaries and finally for roads inside built-up areas.
3.3.1 Access Roads outside built-up areas

Access roads are recognisable by the fact that they comprise a single carriageway without traffic lane markings and are possibly visually narrowed with recommended lanes. Marking on carriageway widths of less than 5.5 metres is inadvisable. On carriageways 5.5 metres and wider, recommended lanes are possible with broken lines and without bicycle symbols. Cycle tracks do not occur on access roads. The speed limit never exceeds 60 km/h. The maximum speed is 30 km/h at intersections and connections. Access road intersections have to be equal. Speed control measures are desirable here.

At intersections of access and distributor roads, physical speed inhibitors are unnecessary. It is better to place physical speed inhibitors on road sections just before the intersections. Roundabouts or traffic control systems are in fact a possibility at such intersections. Situation-dependent solutions remain requisite. In 60-km/h areas, standard signs (for cars) are not needed. Signs may be a good idea for cycle tracks through these areas. It is best to make brick access roads. For practical reasons, however, asphalt and concrete should not be excluded. In those cases, print surfacing can be chosen. Crossings for pedestrians are normally provided with speed inhibiting measures. At crossings with major solitary cycle routes, the cycle routes have right of way. Preferably, the crossing will be a plateau. Stopping and parking along the road is basically permitted but is determined by local circumstances. Public transport vehicles (buses) simply stop on the carriageway. Provisions for breakdowns (emergency lanes) are unnecessary. On narrow roads, shoulders that can bear driving on or passing places are desirable, however.

The distance for obstacles on the shoulder is 4 metres from the edge of the road. In principle, bicycle traffic will be mixed with other traffic on access roads. In exceptional cases where a separate cycle track is present, mopeds are to stay on the carriageway [ref. 4].

3.3.2 Distributor Roads outside built-up areas

Distributor roads are characterised by broken edge lines. Maximum speed on these roads is 80 km/h on road sections and 40 km/h through intersections. Depending on the number of traffic lanes, intensity and spatial possibilities, a “central reserve” (or centre lane) is opted for, along which run continuous edge lines or a double axis with vertical traversable elements between. The number of lanes per carriageway depends on the intensity and desired traffic flow. On a two-lane road, a local passing lane for longer road sections is an option, e.g. directly after an intersection. Distributor roads always have separated carriageways. There are direction signs and advance direction signs. Distributor roads have an impervious asphalt or concrete surface. Property along the road is accessible via parallel access roads or entry roads (dead-end parallel roads). Crossings are preferably at a different level or at the same level at intersections. Same level crossings with cycle or pedestrian tracks are only possible with physical speed inhibitors before and after crossings on distributor roads. Crossings for pedestrians are not marked as pedestrian crossing spots. Parking and stopping only occur in separate parking facilities. Stops for public transport (buses) are at the side of the road or separately situated. A shoulder that can be driven on will suffice for breakdowns. An obstacle distance of 7 metres is advisable along distributor roads.

Cyclists are not permitted on distributor road main carriageways. A separate provision is necessary in the form of a parallel road (which will have the status of an access road) or a separate bicycle track. Slow-moving motorised traffic is undesirable.
3.3.3. Through Roads outside built-up areas
Through roads have full longitudinal markings and hard (non-traversable) carriageway separation. The maximum speed on this type of road is 100 km/h or 120 km/h. Connections consist solely of exit and merging lanes. Crossings are always at a different level, also for slow-moving traffic. Direction signs comprise advance direction signs and junction signs. All through roads have an impervious concrete or asphalt pavement. Woonerf connections are not permitted. Stopping and parking on through roads is prohibited. Public transport (bus) stops are separated from the carriageway. Emergency lanes are required along all through roads. The obstacle distance is 10 metres at 100 km/h and 13 metres at 120 km/h. Cyclists and slow-moving motorised traffic are not permitted on through roads. There are no speed inhibiting measures on these types of roads.

4. Road types
In principle various differing types of road or methods of execution may be applied for each category of road. However the greater the number of methods of execution and design techniques used in construction, the more difficult it becomes to guarantee that the differences between various road types, and therefore also the individuality of road categories will remain distinctly recognizable. This unique identification is one of the essential principles of the concept of Sustainable Traffic Safety. The road user recognizes a category of road by the consistency of its’ unique characteristics and design elements. Localized features which distinguish a road category, such as the uniformity of design of intersections, also help to make a road category distinctive.

Possible types of road or design features of individual categories of road should comply with the following conditions:
- the essential features of a particular category of road are not allowed to be applied for a different road category (they should be individually distinctive features which are unique to a particular category of road)
- the types of road applied in each individual road category should exhibit all the essential characteristics of that category.
- the number of road types per category of road should be kept to a minimum so that the road category is easily recognizable to the road user.

In the concept of Sustainable Traffic Safety the road is not only carefully designed to fit in with its surroundings, but is also visibly attuned and designed to stimulate a certain driving behaviour and type of traffic which is dictated by the Highways authority on the three categories of road. The design requirements should therefore be formulated in terms of the behaviour expected from the various participants in traffic. Clarity and uniformity of the scene facing road users in each category and type of road are therefore extremely important factors.

The various types of road and their various characteristic features are indicated in the table below.

The national through roads (primary distributors such as trunk roads and motorways) form the road network of the highest order in the hierarchy. These roads are used for primary journeys between different regions of a country and the relevant economic and cultural centres, as well having importance in terms of international relations.
Regional through roads form the link between the regions and the relevant centres. They also complement the network of national through roads thereby creating sufficient density in the through roads network.

<table>
<thead>
<tr>
<th>Category of road</th>
<th>Type</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through roads</td>
<td>type I (national through road)</td>
<td>motorway, maximum speed 120 km/h</td>
</tr>
<tr>
<td></td>
<td>type II (regional through road)</td>
<td>trunk road with limited access, maximum speed 100 km/h</td>
</tr>
<tr>
<td>Distributor roads</td>
<td>type I</td>
<td>single carriageway, transverse profile 2x1 traffic lanes</td>
</tr>
<tr>
<td></td>
<td>type II</td>
<td>dual carriageway transverse profile 2x2 traffic lanes</td>
</tr>
<tr>
<td>Access roads</td>
<td>type I</td>
<td>edge of carriageway marking, with cycling provisions, width of paving $&gt; 4.50$ m</td>
</tr>
<tr>
<td></td>
<td>type II</td>
<td>no edge marking, cycle traffic on carriageway, width of carriageway $\leq 4.50$ m</td>
</tr>
</tbody>
</table>

Within the category of distributor roads it is necessary to make the distinction between the two road types due to particular reasons concerning capacity. The choice of one of the two road types is mainly determined by the relationship between the (forecast) volume of traffic and the capacity of the distributor roads in question.

Opting for two types of access roads is mainly concerned with the function which the road has within the network. Even with this category of road it is mainly because of reasons of capacity that two types of road are identified.

5. Translating into concrete guidelines.

In the Netherlands there are Guidelines for the Design of non-motorways outside built-up areas known as RONA. These guidelines date from the period between 1980 and 1992 and weighing most heavily in 1986. Apart from the fact that these guidelines are somewhat outdated, they have also since been superseded by technical and social developments which justify the necessity for a revision of these guidelines. The revision process is currently underway and the new version of the RONA is expected to appear by the spring of 2001. The process should eventually result in a set of guidelines for designing roads outside built-up areas,

- based on the latest technology, where the emphasis is heavily placed on the concept of Sustainable Traffic Safety and
- in line with the wishes and needs of the present and future guideline users (designers) and
- thanks to the content, composition and design configuration, they can be kept efficient and effective, up to date and manageable.

The aim of the guideline is to:

- provide the user with expertise, based on the most recent technical and social developments at national and international level and also based on practical experience. Particularly those new developments and insights such as given in Sustainable Traffic Safety have been included and elaborated on. This new expertise
may be applied with the design of new roads or the reconstruction of existing roads outside built up areas.
√ offer a tool which may be used as a testing mechanism and instrument of assessment as well as being used in process description, particularly in new construction work, reconstructions and participation procedures.

5.1 Latitude
It has previously been indicated that the guidelines are based on the principles of Sustainable Traffic Safety, especially the infrastructural elements thereof. Within these principles the range of latitude or scope has been set out. This latitude is in line with the wishes of users that have expressed the necessity of such. Local situations and circumstances (space, environment, aspects of landscape and finance) often compel the designer to deviate from guidelines and recommended values. Having insight into the consequences of the deviations provides a well-founded basis for the assessment and decision making process. It makes the designer aware of the consequences of particular actions and decisions.

Though designers are given latitude to find good solutions, it is not intended that they exceed given limiting values (ranges of latitude). If a deviation is unavoidable, then the designer will have to consider the consequences related to such. Answers must be found to the following questions:
√ Where and why can a particular design not be carried through in accordance with the guidelines?
√ To what extent should a guideline be deviated from?
√ What consequence(s) might this have for traffic flow, road safety, the environment, land use and costs?
√ Which (counterbalance) measures may be applied in order to entirely or partially prevent adverse consequences?

5.2 Structure of the guidelines
The new guidelines must be laid down in a practical manner. For this reason the following basic assumptions have been set out:
√ every category of road has been subdivided into two types of road;
√ an ideal profile has been set out for each road type. The ideal profile will include the essential features of the relevant category of road;
√ the ideal profile is supplemented by ranges of scope or latitude. This offers designers the latitude to configure the road lay-out according to their own insight and those elements characteristic of the area in question, while incorporating the philosophy of Sustainable Traffic Safety;
√ the ranges of scope are provided with consequences, in the sense of effects on traffic safety and/or traffic flow;
√ where possible phased measures are to be applied.

The scope may be defined as that ‘distance’ between the minimum and maximum values. As long as design remains within this range or scope then it is consistent with the guideline. However designers should be thoroughly aware that the ‘adding up’ of several minimum values may lead to severe problems.
In most cases the quality of road safety and traffic flow is best served when the road category conforming with the ‘ideal’ can be worked out. In practice this is often not feasible and the road will have to be phased or realized with some deviation in dimension (range of scope). Phasing may be defined as carrying out the construction or reconstruction of a road in phases (temporary state in development). It should be noted here that only the non-essential design elements may be applied in a phased manner. In addition there are two important points deserving of attention:

√ the phased design should be based on the ‘ideal’ design, so that any design elements which are still missing may be easily incorporated in due course. In this way the destruction of capital may be avoided.

√ the negative effects should be limited as far as possible by means of (simple) compensatory counterbalance measures.

5.3 Concrete examples in the guidelines
In order to clarify the guidelines, a number of examples are given below with respect to the ideal profile, phasing options and ranges of scope.

Ideal transverse profile of access road type I:
In the table below the ideal profile is given for the type I access road, supplemented by the minimum and maximum profile.

<table>
<thead>
<tr>
<th></th>
<th>ideal / normal</th>
<th>minimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. width carriageway</td>
<td>3,50</td>
<td>3,50</td>
<td>4,00 – 4,50</td>
</tr>
<tr>
<td>b. edge or manoeuvring strip</td>
<td>0,50</td>
<td>0,25</td>
<td>1,25</td>
</tr>
<tr>
<td>d. marking</td>
<td>0,10</td>
<td>0,10</td>
<td>0,10</td>
</tr>
<tr>
<td>g. cycle track–one-way on each side</td>
<td>2,50</td>
<td>1,50*</td>
<td>2,50</td>
</tr>
<tr>
<td>h. partition strip or reserve</td>
<td>1,50</td>
<td>1,50</td>
<td>1,50</td>
</tr>
<tr>
<td>i. shoulder or verge obstacle-free zone</td>
<td>0,50</td>
<td>0,50</td>
<td></td>
</tr>
</tbody>
</table>

sizes in metres
* mopeds on carriageway

Phasing proposal for distributor roads:
Under normal circumstances there is no overtaking on distributor roads and the carriageway is closed to slow-moving motorized traffic. The statutory maximum speed limit is 80 km/h for passenger cars as well as goods vehicles and buses. Overtaking is not necessary and therefore it is also unnecessary to provide for an overtaking sight distance. In order to avoid potentially very dangerous overtaking manoeuvres on this type of road the transverse profile should be provided with a partition strip or reserve which is very difficult to drive on.

When complete prohibition of slow-moving traffic has to be realized in phases, then it has to be possible to overtake such slow-moving traffic. In this case a broken line is applied on condition that traffic volume is not too high and that there is adequate overtaking sight distance.

Scope of obstacle-free zone on through roads:
The obstacle-free zone is understood to be the area running parallel and adjacent to the carriageway where no obstacles are allowed. The proportion of individual accidents occurring
on the hard shoulder of road sections on the existing single carriageway roads in The Netherlands is extremely high. Due to concerns about road safety affecting the occupants of the relevant vehicles, the area adjacent to the carriageway is kept obstacle free. Only those elements which would not result in damage, in the case of a collision, are allowed within this zone. The following table indicates the width dimensions (standard values) for the obstacle-free zone:

<table>
<thead>
<tr>
<th>design speed $V_d$ (km/h)</th>
<th>Width of obstacle-free zone standard value (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>10.00</td>
</tr>
<tr>
<td>$60 &lt; V_d &lt; 90$</td>
<td>6.00</td>
</tr>
<tr>
<td>$\leq 60$</td>
<td>4.50</td>
</tr>
</tbody>
</table>

When the standard value is deviated from any resulting increase in the number of individual incidents is considered acceptable. The relevant dimensions are given in the table below (bands).

<table>
<thead>
<tr>
<th>design speed $V_d$ (km/h)</th>
<th>width of obstacle-free zone bands (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>8.00 – 10.00</td>
</tr>
<tr>
<td>$60 &lt; V_d &lt; 90$</td>
<td>4.50 - 6.00</td>
</tr>
<tr>
<td>$\leq 60$</td>
<td>4.50</td>
</tr>
</tbody>
</table>

6. The further process of Sustainable Traffic Safety and the Guidelines
The four various Road Authorities in The Netherlands are currently busy with the first part of Sustainable Traffic Safety, the so-called Starting phase. In a jointly signed agreement the philosophy behind Sustainable Traffic Safety is set out and measures are indicated which could be realized in the short term.

In order to be able to fully incorporate Sustainable Traffic Safety into the Dutch road network, a new agreement is currently being composed i.e. ‘Sustainable Traffic Safety phase two’. The guidelines play a significant role in this as they complement the measures included in the second phase, particularly in the area of infrastructure.

A concept of the guidelines has already been produced and this will be assessed and commented on by about 300 people by October 2000. The definitive version of the texts is expected to come out at the end of this year but this will depend on the amount and certainly of the content of such commentary. The guidelines will subsequently be submitted for the final approval of texts to the various umbrella organizations of the Road Authorities. If the guidelines are then agreed they will appear on the market in the spring of 2001.

After that the introduction and transmission of the content of the information in the guidelines will take place at regional meetings.

Continuous management of the guidelines is needed as new developments and experience gained is being constantly gathered with Sustainable Traffic Safety in mind.
References:

1. SWOV; Naar een duurzaam veilig wegverkeer; Nationale Verkeersveiligheidsverkenning voor de jaren 1990/2020; Leidschendam 1992.
2. Kraay, Joop H.; Dutch approaches to a sustainable safe road traffic system, Workshop on traffic safety South Africa - The Netherlands; Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat, Adviesdienst Verkeer en Vervoer, July 1999.
3. CROW; Publicatie 116; Handboek Categorisering wegen op duurzaam veilige basis; Deel I (Voorlopige) Functionele en operationele eisen; Ede 1997.
4. Infopunt Duurzaam Veilig Verkeer; Duurzaam veilige inrichting van wegen buiten de bebouwde kom -een gedachtenvorming; Ede 1999.
5. CROW; Publicatie 135; Bebouwdekomgrenzen; Aanbevelingen voor locatie en inrichting; Ede 1999.
6. Infopunt Duurzaam Veilig Verkeer; Duurzaam veilige inrichting van wegen binnen de bebouwde kom -een gedachtenvorming; Ede 1999 (in preparation).
7. CROW; Record 15; ASVV; Recommendations for traffic provisions in built up areas; Ede 1998.

Further reading:

1. Infopunt Duurzaam Veilig Verkeer; Handleiding Startprogramma Duurzaam Veilig; Deel I Achtergronden; Ede 1998.
2. Infopunt Duurzaam Veilig Verkeer; Handleiding Startprogramma Duurzaam Veilig; Deel II Uitwerking; Ede 1998.
3. Infopunt Duurzaam Veilig Verkeer; Handleiding Startprogramma Duurzaam Veilig; Deel III Voorbeelden; Ede 1998.
4. Talens, Hillie and Teun de Wit; Traffic calming in the Netherlands; ITE Annual Meeting; Las Vegas 1999.
5. Infopunt Duurzaam Veilig Verkeer; Ideeën bundel; Duurzaam Veilig in ontwikkeling; Ede 1998.
Measures to reduce speed in housing areas specifically; physical measures (bumps), low speed zones (30 km/h).

Measures to reduce speed in urban areas in general; environmentally friendly streets, automatic speed control (ATK), intelligent speed adaptation (ISA).

Technical measures; seat-belt reminders, alcolock.

Measures to improve driver behaviour through cooperation with employers – discussed under technical measures.

All of these measures are shown to have a significant impact on traffic safety (see Trafikksikkerhets håndboken, Elvik 1997). Road investments and measures in housing areas and cities are the most efficient, including technical measures for reducing speed. The least efficient are measures to reduce speed in sparsely populated areas.

A substantial part of the reduction in the most serious accidents around 1970-80 was caused by the obligatory use of seatbelts. It is therefore natural that obligatory, technical reminders for such use also have an effect. 90 per cent of drivers and passengers outside urban areas use a seatbelt, 70 per cent inside.

Facts about decision-making processes

The ideal situation for a project like this would be to study actual, historical decision-making processes for similar measures or to look at the implementation of measures under vision Zero as they unfold. For several reasons this has not been possible. Instead we have gathered information from studies in general concerning traffic safety measures to see what possible conclusions we can draw from these. We have also included studies on such processes in other fields, inside the transport sector, or outside, to get a wider material for consideration.

The study of the implementation of obligatory use of seatbelts in USA is the most comprehensive example from the field of traffic safety. Arvid Strands study of “Action Safe School Roads” in Norway is also worth mentioning. We have also looked at some studies around road-building where one goal has been to improve traffic safety and the environment. The majority of these studies are old, 20 to 30 years.

Conflicts of a more general nature within road-building processes was the main topic for a series of studies in Norway and Sweden some 15 years ago. The main outcome from these studies was to show the necessity of spending time in the process, to solve such conflicts as existed, and not try to hide them.

Charging for the use of roads has been a topic in Norway, and some other countries, over the last 10-15 years, to finance building and if possible to influence demand. The main experience drawn from the implementation of such taxes (road-pricing) is how the process is connected to actors and how conflicts
are sought to be solved, f.ex. the negotiations around the “Dennis-package” in Stockholm.

Experiences from public reforms
Any successful decision-making process has to fulfill some or all of the following conditions:

- The goals for the reform work must be relatively unambiguous and not conflict too much with other important, societal objectives.
- The decision-makers must hold substantial knowledge about causes and effects within their field of work, especially concerning goals and the necessary measures to reach these goals.
- The process must be adapted specially to the chosen measures, ideally through one specific organisation, legitimated by law.
- Too many participants make it difficult to foresee the results of the process (anarchy).
- The existence of vetopoints, where one or more actors can block the process, must be considered early in the proceeding work.
- Clear and positive attitudes towards the work at hand among those involved, are important for a successful implementation.
- It is of vital importance to seek support from powerholders and interest-groups outside of the process itself.
- Changes in economic, social and cultural conditions may imply changes in goals and possible measures.
- Measures must be designed to make compromises possible. A “we are right”-attitude can be a serious obstacle to a successful result.
- The will to negotiate is important for meeting objectives, even though this may imply the changing of aims and measures through the process.

This list can be viewed from the top-and-down or from the bottom-and-up. The correct way to start depends on the degree of conflicts and the kind of measures. In situations with considerable amounts of conflict it is always of importance to focus on confidence, build common understanding of the realities concerning the situation at hand, have respect for the values of others involved and focus on solutions that benefit all actors involved.

Feasible actions
Improving traffic safety is probably easiest done in combination with improving road infrastructure. This may seem surprising since most road building is
promoted to increase speed and improve accessibility in general. Implementation is
most likely if actions to improve traffic safety also advances other goals. Road
projects also has a strong and homogenous organisation to further their
implementation.

Larger road projects must however fulfill certain criteria to function as measures
for improving road safety. First of all the new road must not lead to increased
speed, which means stronger speed regulation. Second the new road must not
enhance more traffic, which also means more accidents. Environmental problems
and extensive land-use are severe objections to new roads. The planning system,
however, is structured to search for solutions to such conflicts, through
negotiations between national road administrations on one hand, and regional and
local authorities on the other. The question of costs has, in Norway and other
countries, been solved through the use of user payment. Swedish authorities also
discuss such actions. New roads are often backed by strong societal interests,
because they may promote cheaper transport and economical growth.

Measures to prevent collisions, median barriers, have been discussed to improve
safety in the old network, as an alternative to new roads. This is only possible
where the existent road is wide enough to allow three lanes with a psychological
divider. In Norway this is a most unlikely solution due to narrower roads and the
fact that such solutions improve safety, and only that. The only possibility for
such solutions to be successfull is to implement them on roads where larger
accidents have occurred. Through public attention around such instants one may
obtain enough support for actions, and not through more general analysis’ of
where the measures is most justified.

Street enhancement projects, with focus on safety and the environment, has been
tried in some Norwegian cities and towns. The possible success is based on
synergies between environment and safety, even though the main effect seems to be
upon safety, and not, as expected, on noise and pollution. The experiments have so
far also shown how it is possible to further cooperation between national and local
authorities. Such solutions have so far only been possible to implement in smaller
communities with a limited amount of through-traffic. In Norway the only
exception is the town of Horten, with less than 20000 inhabitants. Such actions
will be of greater interest when tried out in larger cities.

The most difficult measures to implement are those related to lowering speed, and
enforcing speed regulations, even though such measures are most effective to
reduce the number of accidents. Lower speed limits and controls by police,
through surveillance cameras or by use of information technology, are all
problematic. The main reason for this is the conflict between the amount of time
spent in traffic and safety. Such actions also suppose a strong cooperation
between road authorities and the police. So far the police does not seem to give
traffic safety high priority when in conflict with crime prevention in a more
general sense.

It is of great importance not to make the public believe that lower speed and speed
controls is an easy and popular task. If so one often ends with symbolic acts. The
decisive question is to focus on speed regulation where it is effective, not in too much conflict with fast and efficient transport and where participation by the police is not essential. This is mostly the case in larger cities, and especially in housing areas, where low speed can be enhanced through the use of physical obstacles.

The last group of measures are based on technical solutions that can help people to avoid the most deadly aspects of driving, not using seat belts and driving when under the influence of alcohol or drugs. Obligatory use of seat belts have been part of traffic legislation over the last 15-25 years. The share of users are 90 per cent in sparsely populated areas and 70 per cent in cities. A device that reminds or forces people to use seat belts, exists. The same is the case for alcolocks. Such solutions however take time to be implemented. In Europe seat belts existed for nearly 20 years before the use was promoted by law. In USA obligatory use of seat belts was approved in 1986. One reason for such long time periods is that regulations conflicts with the emphasis on personal freedom to act as one wants even though the result may be fatal.

Technical solutions may also be costly and must therefore fulfill other purposes than just safety. This is probably the case when discussing ISA (Intelligent Speed Adaption). ISA has a great potential, but only if there also is a need for electronic maps and route guidance.

These conclusions may seem obvious and debatable at the same time. To an extent they can be seen as hypothesis’ rather than substantial truths. Most of all the discussion above focuses on possible processes towards solutions rather than simple introductions of “measures with greatest effect”.

Top-down or bottom-up
I have focused on vision zero and traffic safety measures as governmental reforms, implemented from above. In organisational theory this approach is named top-down. A good alternative, both theoretically and in practical reform work, is a so-called bottom-up perspective. With this alternative one focuses, not on rigid objectives and given solutions, but on the network that exists (locally and centrally) or will be promoted to work with possible solutions. The role of national government in such situations will be to provide resources and start the process working, if involved at all. The focus for local actors will be, not on specified goals, but on processes and compromises, more or less independent of central objectives.

There are several reasons for such a perspective to be a better solution and also give a better description as to what really happens. The main reason is that it is hard, if possible, to fulfill all the requirements listed earlier. Conflicts will always exist, external conditions always change, one does not always know the best mean for given ends, and so on. The main problem related to a vision is that it may lock
the process to given and in many cases, unobtainable objectives. The challenge is to use visions as inspirations, not as deadlocks.
Litterature:
Elvik, Rune 1997: Trafikksikkerhetshåndboken, Institute of transport economics, Oslo 1997

TOWARDS GLOBAL STANDARDISATION – REDEFINING FATALITIES

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1. Background

There is an ever-increasing tendency towards standardising principles, policies and practices world-wide. As far as the definition of a traffic accident fatality is concerned, however, there is still a large range of definitions currently in use by different countries. Some of the more common definitions include: immediate death and death within 24 hours of a traffic accident (Portugal), or death 3 days (Republic of Korea), 7 days (Italy), 30 days (most European countries) or 1 year (USA) after a traffic accident.

The wide variety of definitions makes comparisons between different countries difficult. In 1993 the United Nations Economic Commission for Europe (UN/ECE) adopted the following definition of a person killed in a traffic accident: “any person who was killed outright or who died within 30 days as a result of the accident” (United Nations, 1993). This was the first international attempt at trying to standardise the definition of a traffic accident fatality. Since 1993 the following countries have adopted the 30-day definition: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Israel, Japan, Luxembourg, the Netherlands, Norway, the Slovak Republic, Spain, Switzerland and the United Kingdom (Mónica Colás Pozuelo and Izarzugaza, 1996).

Attempts have also been made to develop (universal) correction factors to allow for comparison amongst countries with different fatality definitions. However, applying such correction factors is problematic because of differences in the quality of road infrastructure, vehicle safety and medical management between countries (and over time). These influence the survivability of victims and consequently the validity of such factors (Mónica Colás Pozuelo and Izarzugaza, 1996). The ultimate solution would be to encourage the global standardisation of the definition of a traffic fatality in accordance with that prescribed by the UN/ECE. But even this introduces new problems (Mónica Colás Pozuelo and Izarzugaza, 1996). The longer the period in which a traffic accident casualty dies after an accident, the greater the chance the cause of this death is not registered as being from a road traffic accident but rather from complications which arose from the accident (e.g. pneumonia after fractured ribs sustained by a vehicle driver during an accident). The accuracy of fatality statistics is therefore diminished by longer-period definitions of traffic accident fatalities. An additional problem is that such definitions require long follow-up procedures that are very time consuming for police and hospital staff. These require regular visits or phone calls. The “longer” the definition, the more administration and resources required. To complicate matters further, these follow-up procedures are generally more established in larger
hospitals, which admit large numbers of traffic accident casualties. For smaller hospitals, where the frequency of admission of traffic accident casualties is low, such procedures may not even exist. Where police are not involved in the recording of accidents or the transport or admission of traffic accident casualties, alternative follow-up procedures may not be in place or effective.

In the light of the above-mentioned problems, this paper investigates the consequences of using the 6-day definition in South Africa, the merits of changing this definition to a 30-day definition, as well as the possible implications this is likely to have in terms of procedure and processes.

2. **Situation in South Africa**

Up to 1975, the official definition of a fatal motor vehicle accident in South Africa was one where death occurred within three months of an accident. Thereafter (from January 1975) the definition was changed to death within 6 days of an accident. The process by which traffic fatality data is recorded and collected in South Africa is depicted in Figure 1 below.

![Figure 1. The process through which traffic fatality data is recorded and collected in South Africa](image)

In terms of the National Road Traffic Act No. 8 of 1998, all motor vehicle accidents resulting in serious injury or death have to be recorded on a standard accident report form by either a police or traffic officer. With fatal accidents a police docket is also opened, and a case of culpable homicide investigated by the police against the drivers of the vehicles involved. As information from the accident report forms have to be incorporated into the homicide investigation, the
original accident report forms sometimes disappear within police dockets. Seriously injured casualties are sometimes rushed off the scene of the accident to hospital without being recorded on an accident report form. Occasionally, slightly injured casualties land up in hospital (without having to be recorded in terms of the Road Traffic Act) and subsequently die of their injuries.

In South Africa there is no formal follow-up procedure for tracking the progress of specifically traffic accident casualties en route to hospitals or while undergoing hospital care. The accident report forms are therefore not updated as far as fatalities are concerned. They consequently only really reflect ‘dead on the scene’ cases. The police reported fatalities are therefore heavily underreported when compared to actual fatalities.

There is an indirect method of establishing the eventual outcome of traffic casualties. The Births and Deaths Registration Act, 1992 (Act No. 51 of 1992) stipulates that all deaths have to be registered on a death certificate by a medical practitioner or a professional nurse. In terms of the same act and the Inquests Act No. 58 of 1959 (as amended) all deaths due to non-natural and undetermined causes, including traffic accidents, are subject to a medico-legal investigation (including an autopsy), by a district surgeon or forensic pathologist. The onus rests almost exclusively on the doctor or nurse to determine whether the deceased died as a direct or indirect result of a traffic accident and if so, what the approximate length of time between the accident and death was. The latter requirement was, however, only incorporated into the new Death Certificate that has been in usage since 1998. Consequently, the validity of this variable has yet to be assessed.

There are basically two national accident databases containing fatality records. The National Department of Transport maintains general accident data on its National Traffic Information System (NaTIS) as recorded on the standard accident report form; while Statistics South Africa (STATSSA) captures mortality data from the Death Certificate on its Vital Stats database. As a result of capturing and recording problems previously described, NaTIS fatality data reflects reasonably accurate Dead on Arrival (DOA) information and to a lesser degree major injuries but very few minor injuries. Traffic accident casualties dying after admission to hospital, even within 6 days, are rarely recorded on NaTIS. Although its data is less than optimum NaTIS can provide fatality data relatively quickly. In addition to NaTIS, during peak holiday seasons, such as Easter and Christmas (and as part of the national “Arrive Alive” Road Safety Campaign), all police stations across the country are required to fax all fatal accident forms (DOA’s only) to the NDOT immediately after the accident has occurred. Despite the improvement in the availability of fatality data during this time, the accuracy of the data is still questionable. The STATSSA data would have a better sample of patients who die in road traffic accidents, but as mentioned earlier, this data is also imperfect because many doctors fail to record the cause of the injury. In as many as one-third of the non-natural cases the cause of injury is recorded as “undetermined” on the Death Certificate. Furthermore, since STATSSA only records Death Certificate data some years after an accident has occurred, it becomes virtually impossible to investigate and determine the “undetermined” causes of injury. This backlog can sometimes extend to 5 years. The backlog for capturing accident data onto NaTIS is significantly less (up to 6 months). With the recent introduction of a new accident report form, this backlog has increased.

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1 Non-natural causes in terms of the International Classification of Diseases (WHO 1977 p 763), are defined as “the circumstances of the accident or violence which produced the fatal injury”
3. Case study

Recognising the need for a concerted response to injuries in South Africa, in 1996 the Essential National Health Research Congress identified research for injury and violence prevention as a top priority. Furthermore, in 1997 the development of a public health response to violence and injury was itemised as part of the US-South Africa Bi-National Commission. In July 1997 a consultative conference on health and violence prevention prioritised the development of an injury surveillance system.

In 1998, funding was obtained from the Department of Arts, Culture, Science and Technology’s (DACST) Innovation Fund for crime prevention. A consortium of researchers (MRC [lead organisation], UNISA [Health Psychology & Centre for Peace Action], CSIR [GIS Department]) were commissioned to develop an injury surveillance system which had three components, viz.:

- a national non-natural mortality surveillance system (NMSS);
- a national non-fatal injury surveillance system (NNFSS);
- the sentinel surveillance of trauma and drugs (TAD).

The National Non-natural Mortality Surveillance System (NMSS) was piloted in 1998 but formally started at the beginning of 1999. It collates information readily available from the documentation that arises from medico-legal post mortem investigations (Butchart, Matzopoulos, Peden, et al, unpublished manuscript). Currently, 10 mortuaries in 5 different provinces contribute their data to this system. In 1999 there were 12 269 cases registered in the database. This sample represents about one-fifth of the approximately 60 000 non-natural deaths registered annually in South Africa. This data has been validated and found to be sufficiently accurate for generalisations to be made. Of these deaths, 3 464 were due to transport-related collisions. The vast majority of these collisions were classified as ‘accidental’. In only 7.3% of cases, was the cause of the collision undetermined pending a court investigation, e.g. hit-and-run cases.

The date of death and date of injury are included in the database but the latter variable is relatively difficult to obtain in many cases, particularly where accident casualties have gone through a hospital facility or died later. This is usually because the hospital folder does not go to the mortuary and if the doctor (who completes the forms for medico-legal post-mortem request) does not indicate when and why the patient was admitted, then the forensic pathologist who does the post mortem does not get this information. Consequently, the date of injury and date of death were only available in 54.8% of the traffic cases in the database. The results presented here are therefore an underestimate of the actual proportion of cases who die between 7 and 30 days after injury. Bearing the limitations of this study in mind, Table I indicates that 7.2% of cases died between seven and thirty days after their injury.
Table 1. The percentage of traffic accident casualties dying as a result of their injuries for various periods after the accident.

<table>
<thead>
<tr>
<th>Delay to death (in days)</th>
<th>%</th>
<th>Cumulative %</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>76.4</td>
<td>76.4</td>
<td>74.4 - 78.3</td>
</tr>
<tr>
<td>1 – 6</td>
<td>14.7</td>
<td>91.1</td>
<td>13.1 - 16.3</td>
</tr>
<tr>
<td>7 – 30</td>
<td>7.2</td>
<td>98.3</td>
<td>6.0 - 8.4</td>
</tr>
<tr>
<td>31+</td>
<td>1.7</td>
<td>100.0</td>
<td>1.1 - 2.3</td>
</tr>
</tbody>
</table>

Using the above data, a conversion factor of approximately 1.08 (98.3/91.1) may be deduced. This compares favourably to the correction factor of 1.10 derived by Smeed (1968) for fatalities occurring within 7 days of an accident.

For as many as 43.8% of the cases the traffic user category was unspecified, but pedestrians accounted for almost one-quarter of cases (Figure 2).

Figure 2. Proportions of traffic users fatally injured in traffic collisions

STATSSA recorded 9 068 fatal injuries in South Africa in 1998. According to the conservative estimates that arise from this study, if fatal traffic accidents were defined according to the UN/ECU definition, the actual total would be approximately 9 793 (9 068 X 1.08) if it is assumed that the correction factor for 1999 was the same as for 1998. This is an additional 725 fatalities, which translates roughly to an additional cost of R226 million ($33 million) to the country. Clearly, the consequence of not using the UN/ECU definition is quite significant – traffic accident fatalities for South Africa and its impact on the country’s economy are even worse than
generally depicted. This would, however, have to be weighed against the cost of traffic officials having to follow up patients in hospital. At present this change cannot be estimated in monetary terms but would involve changing the present accident report form again, training officers and doctors alike, follow up costs etc.

4. Discussion

The starting point in considering whether to change from the present definition of a fatality to the definition prescribed by the EU/ECE is to determine the minimum level of accuracy required for international comparisons. The next step would be to determine the once-off and recurring costs required by the South African government in terms of improved procedures/processes, additional manpower and administration to ensure this minimum level of accuracy is maintained. This has to be compared to the alternative of keeping the current definition of accident fatalities and merely applying a correction factor that is reviewed periodically. However, even for this alternative, improved procedures/processes will be required to ensure a minimum level of accuracy in the fatality data. But, as the assessment of the financial implications of both alternatives is beyond the scope of this paper, only the possible processes and procedures for the alternatives are discussed here.

A number of problems have been mentioned that inhibit accurate fatality data collection in South Africa. These include:

- the request for an approximate length of time between the death and the cause of death (traffic accident) on the death certificate, and the consequent poor estimates made on this;
- doctors failing to indicate the cause of injury on the death certificate (specifically with regard to traffic accidents);
- lack of formal follow-up procedures for tracking the progress of traffic accident casualties en route to hospitals or in hospital care;
- the backlog in capturing of fatalities on both the NaTIS and STATSSA databases, which complicates any follow-up of suspect or incomplete accident or medical records;
- the disappearance of original accident records during the investigation of culpable homicide investigations by the police against the drivers of the vehicles involved;
- the non-recording of some seriously injured casualties on accident report forms; and,
- the non-recording of slightly injured casualties that land up in hospital and subsequently die of their injuries.

The most obvious procedural change that could improve the accuracy of accident fatality data would be amendments to the current death certificate. This would include changing reference to an approximate length of time between the death and the cause of death to one requiring an exact measurement of this period. However, since the form was only changed in 1998 this is probably not feasible. Never the less, this procedural change would be ineffective unless accompanied by the institution of procedures for all hospitals to clearly document seriously slightly injured patients together with the primary cause and time/date of injury. In other words, South Africa requires a national non-fatal injury surveillance system. Such a system is currently being piloted and should be up and running by 2001 in sentinel hospitals around the country. These data could
be used to validate the NaTIS database. This would have to be enforced through appropriate legislation, that in turn would have to be accompanied by proper marketing and training.

It is envisaged to expand the National Non-natural Mortality Surveillance System (NMSS) currently being pilot tested to incorporate all state mortuaries around the country. A rationalisation process that is currently taking place within the Health Department however is unfortunately hampering this roll out. Provided the date of injury was better completed on the data collection form used in this System, this could eventually provide a useful way of correlating traffic fatality data from the death certificates and traffic accident report forms.

Another important procedure that would need to be introduced is for the doctor who completes the forms for medico-legal post-mortem request to indicate exactly when the patient was admitted. In other words, the doctor requesting the autopsy would need to state specifically on the request form when and how the injury occurred so that the Forensic Pathologist could include this information.

The backlog in the capturing of fatality data onto Vital Stats is mainly due to a combination of the extremely large number of fatalities per year and a shortage of data capturers. Historically, military conscripts were used to help capture fatality data, but with the abolishment of compulsory military service, this practice has been terminated, with the result that STATSSA resources for capturing have significantly dwindled.

The problem of accident records disappearing during the investigation of culpable homicide investigations by the police could become worse with the introduction of the new accident report form. This does not have duplicate copies like the old form but relies on photocopies having to be made by the police. This could increase the chances of the form getting lost.

However, the accident investigation procedure is in the process of being taken over by the traffic police. Due to their tasks being more focused on traffic related matters, this could result in an improvement in the quality of accident fatality data. The privatisation of the capturing of traffic accident fatalities, along with various other administrative functions of the traffic police, is being considered. This has the potential to largely reduce the current capturing backlog.

Another, and perhaps the most feasible procedural change that could lead to improved quality of accident fatality data, involves introducing follow-up procedures for traffic police. This has two main advantages:

- the number of traffic fatalities, is considerably less than the number of total fatalities, which should reduce the cost of this procedure compared with procedural changes introduced in the health sector; and,
- the capturing backlog of traffic accident data on NaTIS is considerably less than the capturing backlog of fatality data on the Vital Stats database, meaning that accident fatality data would be available much quicker via NaTIS than via STATSSA.

Quite simply, a procedure could be introduced and legislated whereby traffic authorities, which are responsible for capturing traffic accident data for NaTIS, periodically contact their respective state mortuaries to identify traffic accident casualties that have died as a result of their injuries.

The National Department of Health is currently developing a National Health Information System. This will eventually indicate the number of people living in the country and details concerning the state of their health. There is a possibility of including in the System the cause of
death. This would open up the possibility of creating links to NaTIS to enable traffic accident casualties that die in hospital to be identified.

5. Conclusions and recommendations

The consequence of not using the UN/ECU is quite significant – traffic accident fatalities for South Africa and its impact on the country’s economy are even worse than generally depicted. The change in the definition of accident fatalities for South Africa from death within 6 days of an accident to death within 30 days of an accident should therefore be seriously considered. This however requires further investigation to determine the cost and implication of the procedural changes and amendment in legislation to ensure an acceptable level of accuracy of data arising from the new definition.

6. References


Mónica Colás Pozuelo A. and Izarzugaza J (1996), Follow-up of traffic victims during the 30 days period after the accident, Special Report of the IRTAD Operational Committee, OECD Road Transport Research Programme, Dirección General de Tráfico, Madrid

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Smeed R.J. (1968), Some aspects of pedestrian safety, The substance of a lecture given to the International Federation of Pedestrians, University College, London


AN INVESTIGATION OF TRAFFIC CRASH MIGRATION AT URBAN INTERSECTIONS

by
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ABSTRACT

Safety professionals are often concerned about the installation of safety measures at selected high crash locations due to the potential for the past crash experiences of the improved locations moving to other untreated locations within the same area. It is postulated that increases in the traffic crash experience at untreated locations would occur after improvements were made at only selected treated locations in an area that experiences significant crash reductions. Past research indicates that this ‘migration’ phenomenon is possible under certain conditions.

A public-private partnership project in the City of Detroit, Michigan was initiated in 1996 to alleviate traffic crash and severity problems at select high crash locations. AAA Michigan, one of the largest insurance companies in Michigan, partnered with the City of Detroit, Wayne County, the Michigan Department of Transportation (MDOT), the Office of Highway Safety Planning (OHSP) and Wayne State University, to identify high crash locations and implement low cost countermeasures, in order to reduce crashes and injuries.

Low cost safety treatments were installed at several intersections in the northeast part of the City of Detroit. A “before and after” safety evaluation study revealed that total crashes and injury crashes were reduced by close to 50 percent at the locations where safety improvements were made in 1997. The reduction of right-angle crashes, left-turn head-on and injury crashes were statistically significant.

The purpose of this study was to determine if the intersection locations in the vicinity of the treated sites were experiencing increased traffic crashes and injuries due to traffic crash migration effect.
The results of the statistical analyses for intersections without implemented countermeasures indicated the differences in targeted crash types during the same time period were not significant. Therefore, no migration effects were identified in this study. The results of the statistical analyses performed for grouped intersections with implemented countermeasures indicated significant reductions in traffic crashes for total, injury, right-angle and left-turn head-on crashes.

INTRODUCTION

The process of high crash location identification inherently discriminates between highway locations with a higher incidence of crashes and injuries, and locations with lower crashes and injuries. In fact, various methods of high crash location identification process is supposed to do this, in order to allow safety professionals to allocate scarce resources towards only a limited number of the high crash locations. Safety professionals are often concerned about the installation of safety measures at only a few selected high crash locations that are targeted to reduce crashes and injuries because of the potential for the past crash experiences to move to another untreated similar location in the same vicinity. This phenomenon is often referred as migration of traffic crashes. Past research indicates such migration experiences may be possible under certain conditions. For example, an intersection that was found to have a high incidence of left-turn head-on crashes and was fitted with the countermeasure that consisted of the prohibition of left-turns. The left-turn head-on crashes at the intersection will be reduced to almost nonexistent, however this left-turning traffic may start using an adjacent intersection to make this maneuver and thus, may cause a high incidence of left-turn head-on crashes at a nearby location. This is a simplified example of the migration phenomenon of traffic crashes.

Safety professionals are often concerned about the migration of traffic crashes to adjacent locations when only certain locations are treated with crash countermeasures, instead of implementing area-wide safety improvements, especially those treatments which impact driver attention and behavior.

Some traffic and safety professionals hypothesize that if safety improvements are implemented at site-specific intersection locations that experience significant crash reductions, then the crashes may migrate to other surrounding untreated intersections. The underlying assumption to this hypothesis is that at the treated sites, the driver’s awareness for caution may
be lessened. However, as drivers continue to travel through adjacent and similar untreated areas, they may maintain this subdued caution and are more likely to be involved in a traffic crash. Consequently, the risk of a crash in the surrounding areas may be increased as compared to the treated sites.

A public-private partnership project in the City of Detroit, Michigan was initiated in 1996 to alleviate traffic crash and severity problems at select high crash locations. AAA Michigan, one of the largest insurance companies in the state of Michigan partnered with the city of Detroit, Wayne County, the Michigan Department of Transportation (MDOT), the Office of Highway Safety Planning (OHSP) and Wayne State University, to identify high crash locations and implement low cost safety treatments, in order to reduce crashes and injuries.

As a part of this project, low cost safety treatments were installed at several intersections. A “before and after” safety evaluation study at the treated signalized locations revealed that the total crashes and injury crashes were reduced by close to 50 percent at the locations where safety improvements were implemented in 1997 and the reductions were statistically significant. The reduction of right-angle crashes, left-turn head-on and injury crashes were considerable and statistically significant.

The purpose of this study was to determine if the intersection locations in the vicinity of the treated sites were experiencing increased traffic crashes and injuries due to traffic crash migration phenomenon.

BACKGROUND

Boyle and Wright (1) conducted a study in the Greater London Council (GLC) area to investigate crash migration by comparing the crash frequency for three years of “before” and three years of “after” data in treated blackspot locations, as well as in untreated neighboring sites. A blackspot is defined as a location that has experienced high crashes in the past years. The purpose of this study was to determine if a decrease in crashes at the high crash locations were followed by an increase in crashes in the immediate area. The results of this study showed that for 133 sites sampled, there was a decrease in crashes of 22 percent at the treated sites and there was a 10 percent increase in crashes in the areas surrounding the treated blackspot locations.
It should be noted that this study was conducted under several constraints and limitations. Some of these constraints and limitations included the removal of hazardous locations from the sample due to specific location-related concerns and the lack of available crash data.

The paper by Boyle and Wright was critiqued by Huddart (2). Huddart states that it cannot be agreed upon that “the evidence is sufficient to say that accident migration is a real effect, and are certainly concerned that such a statement could unwarrantly impair road safety work.” Huddart also states that the findings of the Boyle and Wright paper are unrealistic due to an unconvincing hypothesis stated to explain the results. This critique also suggested that the statistical analysis used were not robust and that the migration effect was more likely to have been caused by a bias in the data.

McGuigan (3) examined crash migration with the regression-to-mean effect using the data set from the Boyle and Wright study (1). Two years of “before” and “after” data in the Lothain region, London along a corridor was used for this study. The author concluded that the regression-to-the-mean analysis did not prove or disprove the existence of crash migration, but it did however “indicate that at least some, if not a major part, of the ‘migration’ effect reported by Boyle and Wright (1) could be quite simply explained by regression-to-mean”. The author also concluded that in order to demonstrate that improvements implemented at treatment sites are successful, the crash reduction needs to be shown as greater than any effect of regression-to-mean. Similarly, to demonstrate that crashes have ‘migrated’ to areas surrounding the treated site, any observed increase in crashes needs to be greater than the effect of regression-to-mean.

Levine, Golob and Recker (4) in their study observed the migration of crashes associated with lane addition projects on urban freeways. They tested the migration of crashes associated with safety evaluations of freeway expansion projects in Los Angeles and Orange County in Southern California. A “before” and “after” study with control sites was performed and tested using the chi-squared test of significance. The authors concluded that crashes increased in the downstream areas after the improvements due to traffic congestion and that the treatment sites experienced crash reductions due to the congestion relief.

SITE DESCRIPTION

Seven signalized intersections were studied in order to investigate the traffic crash migration phenomenon at urban signalized intersections in the City of Detroit. Three of the seven
Intersections are treatment sites where safety improvements were implemented and the remaining four intersections are the untreated sites. It is important to note that these untreated sites have similar geometric features, traffic volumes and traffic control devices as the treatment sites, before the improvements were implemented. All seven sites are located within a five-mile radius of each other.

The safety treatments implemented for alleviating traffic crash problems at the treated sites included the implementation of yellow change intervals calculated on the basis of measured approach speeds and all-red intervals designed on the basis of roadway geometry. Additionally, there were other safety improvements made at the treated sites, such as providing larger signal heads (30.5 cm (12 inch) diameter) and the addition of exclusive left-turn lanes and left-turn phases, where warranted. Three signalized intersections out of the seven intersections were modified to include these improvements.

The three treatment sites for this study are the intersections of:
- Seven Mile Road and Ryan Road
- Seven Mile Road and John R Road
- Hubbell Road and Puritan Road

All three intersections are located on the northeast side of the City of Detroit. The adjacent land uses around all of the intersections were commercial with the exception of a high school located at the southwest corner of the Seven Mile Road and Ryan Road intersection. These intersections were the treatment sites. The improvements at these locations were all low cost and did not include any pavement widening.

In order to identify if any migration effects existed, four signalized intersections in the same area of the city, including some that were located on the same roads, were studied. They are the intersections of:
- Seven Mile Road and Dequindre Road
- Seven Mile Road and Conant Avenue
- Greenfield Road and Puritan Road
- Schaefer Road and Puritan Road

These intersections have similar geometric features as the three treatment sites, before the improvements were implemented. The traffic volumes and traffic control features were also similar.
All seven intersections (three treatment sites before improvements and four untreated sites) are generally characterized by having extraordinarily wide lane widths (greater than 5.8 m (19 feet) per lane) at each approach, operating on a two-phase signal design, having less than twelve-inch signal heads and lacking left-turn lanes and phases. The adjacent land uses in the vicinity of these sites were similar to the treated sites. It should be noted that the untreated sites either had no, or an insufficient all-red interval and approximately, a four-second yellow interval as the phase change interval. All of the treated sites now however, have properly designed yellow and all-red intervals as a part of their improvements.

SAFETY DEFICIENCIES AND COUNTERMEASURES

Treated Sites
In general, the treated intersections were not properly marked for laneages before their improvements. For example, some legs of the intersections, although 13 meters (43 feet) wide were marked with only a centerline. Thus, creating two 6.6 meter (21'-6") wide lanes. There were also numerous driveways to adjacent commercial developments in close proximity to the intersections. Some of the intersections were experiencing high levels of left-turning traffic, yet all the traffic signals were pre-timed two-phase traffic signals. In most cases, the pavement was deteriorating, cracking and had developed potholes. There were no all-red intervals at the treated sites with the exception of a nominal and insufficient all-red interval at the intersection of Seven Mile Road and Ryan Road.

The countermeasures implemented are as follows:

- Replacing all signals with standard 30.5 cm (12-inch) diameter signal heads
- Providing painted exclusive left-turn lanes at all approaches for all three intersections
- Providing exclusive left-turn phases for Seven Mile Road traffic at Ryan Road and for Seven Mile Road traffic at John R Road
- Providing a 4- second yellow interval at all intersections and providing 1.8 to 2.0 seconds of all-red intervals between all conflicting signal intervals
- Repaving all intersection approaches with asphalt
- Removing on-street parking 61 meters (200 feet) from the intersection at all approaches for all three intersections
• Replacing all missing and deteriorating signs at all three intersections

These countermeasures were targeted towards mitigating total, injury, right-angle and left-turn head-on crashes. Specifically, the implementation of the all-red intervals were to mitigate right-angle crashes and the installation of left-turn lanes and/or phases were to alleviate left-turn head-on crashes.

These improvements were made based on “before” improvement crash experience, traffic volume data and approach speed data. In spite of unequal pavement widths at various legs of the intersections, no modifications were made to alter the basic pavement widths at any intersection in order to keep the improvement costs to a minimum.

TRAFFIC CRASH ANALYSIS

The purpose of this study was to perform a “before” and “after” evaluation in order to determine:

1. The effectiveness of the safety treatments at the treated sites.
2. The effect of crash migration in the surrounding area.

Traffic crash data for all seven sites was obtained for two years “before” (1995 and 1996) and one year “after” (1998) the improvements were implemented at the treated sites. One year (1997) of crash data was excluded from this analysis because this was the time period when the safety treatments were implemented (May 1997 through October 1997) at the treated sites.

Analyses were performed in order to determine the net effect of traffic crashes for the treated sites and the untreated sites. The traffic crash analyses considered each intersection individually as well as a group of sites combined. The crash data for three treated sites were combined to form one group and the other group was formed similarly for the four untreated sites. Table 1 shows the average annual crash experience per location for both groups.
Table 1. Annual Average Traffic Crash Experience Per Intersection for the Treated and Untreated Groups

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>CRASHES</th>
<th>TREATED GROUP OF THREE SITES</th>
<th>UNTREATED GROUP OF FOUR SITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>Total Crashes</td>
<td>59.33</td>
<td>42.50</td>
</tr>
<tr>
<td></td>
<td>Injury Crashes</td>
<td>18.50</td>
<td>13.25</td>
</tr>
<tr>
<td></td>
<td>Right Angle Crashes</td>
<td>21.50</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>Left-Turn Head-On Crashes</td>
<td>10.17</td>
<td>6.50</td>
</tr>
<tr>
<td>AFTER</td>
<td>Total Crashes</td>
<td>26.67</td>
<td>40.25</td>
</tr>
<tr>
<td></td>
<td>Injury Crashes</td>
<td>5.67</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>Right Angle Crashes</td>
<td>6.67</td>
<td>10.75</td>
</tr>
<tr>
<td></td>
<td>Left-Turn Head-On Crashes</td>
<td>2.33</td>
<td>5.75</td>
</tr>
</tbody>
</table>

If crashes were to migrate to the surrounding areas after the installation of safety measures at the treated sites, one would expect the traffic crashes to decrease at the treated sites and increase at the neighboring untreated sites. A trend of the total crashes per intersection for the “before” and “after” period for the treated and untreated groups are shown in Figures 1 and 2, respectively.

Figure 1. “Before” and “After” Crash Data for the Untreated Sites
Crash statistics for the city of Detroit and the state of Michigan were analyzed in comparison to the treated and untreated groups of sites. Table 2 presents the total crashes for 1995, 1996 and 1998.

Table 2. Statewide, Citywide and Study Groups Crash Statistics Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>State of Michigan</td>
<td>421,073</td>
<td>435,477</td>
<td>403,766</td>
</tr>
<tr>
<td>City of Detroit</td>
<td>51,618</td>
<td>54,567</td>
<td>49,245</td>
</tr>
<tr>
<td>Treated Study Group</td>
<td>60</td>
<td>58</td>
<td>27</td>
</tr>
<tr>
<td>Untreated Study Group</td>
<td>37</td>
<td>48</td>
<td>40</td>
</tr>
</tbody>
</table>

From 1995 to 1996, the state of Michigan and the city of Detroit follow similar trends. Michigan’s traffic crash data revealed an increase of 3.4 percent and the city of Detroit also experienced an increase in traffic crashes of 5.7 percent. From 1996 to 1998, the state of Michigan and the city of Detroit experienced decreases in total traffic crashes of 3.6 percent per year for the state and 4.9 percent per year for the city.
For the treated group of intersections the traffic crashes remained almost constant, however from 1996 to 1998 experienced a significant crash reduction of 26.7 percent per year or 53.4 percent in the two year period after the implementation of safety treatments. However the untreated group of intersections followed similar crash patterns as the state and city. From 1995 to 1996, the traffic crashes increased and from 1996 to 1998 decreased by 8 percent per year.

The “before” and “after” study performed at the same three treatment sites as a part of past research indicated statistically significant reductions of 44 to 57 percent for total crashes and 53 to 73 percent reductions in injury crashes [5]. The crash data at the untreated sites for the “before” and “after” periods are presented in Table 3.

Table 3. “Before” and “After” Crashes at the Untreated Sites

<table>
<thead>
<tr>
<th>UNTREATED INTERSECTIONS</th>
<th>AVERAGE ANNUAL CRASHES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BEFORE</td>
</tr>
<tr>
<td></td>
<td>Right Angle</td>
</tr>
<tr>
<td>Seven Mile Road and Dequindre Road</td>
<td>14</td>
</tr>
<tr>
<td>Seven Mile Road and Conant Avenue</td>
<td>11.5</td>
</tr>
<tr>
<td>Greenfield Road and Puritan Road</td>
<td>8.5</td>
</tr>
<tr>
<td>Schaefer Road and Puritan Road</td>
<td>18</td>
</tr>
</tbody>
</table>

Statistical tests were performed for the “before” and “after” periods for the treated and untreated sites using the chi-squared test of significance. This test was used to determine if there were statistically significant differences in the crash experiences in the untreated group during the “after” period. The null hypothesis stated that there are no differences between the “before” and “after” crash data. The alternative hypothesis stated that the “before” and “after” crash frequencies are different.

Safety treatments implemented at the treatment sites were targeted to reduce total, injury, right-angle and left-turn head-on crash types. Therefore, these crash variables were the only ones tested at both the untreated group to assess any migration effects due to crash reductions at the treated sites. An alpha value of 0.05 was used to test the above stated hypothesis for total crashes, as well as for injury, right-angle and left-turn head-on crashes for the untreated group.
At an alpha value of 0.05 and three degrees of freedom, $\chi^2_{critical} = 7.815$ and the calculated $\chi^2$ values were determined for the specific crash variables mentioned earlier. If $\chi^2_{calculated} > \chi^2_{critical}$, the null hypothesis is rejected, the alternative hypothesis is supported and a significant difference in the “before” and “after” crash frequencies are found. However, if the calculated chi-squared value is less than the critical value, then a significant difference is not found in the “before” and “after” crash frequencies. The calculated chi-squared values were less than the critical value for all the categories, therefore the null hypothesis is not rejected. The results of the statistical analysis for the untreated group are shown in Table 4.

### Table 4. Results of Statistical Testing (Chi-Squared Test) for the Untreated Group

<table>
<thead>
<tr>
<th>CRASH TYPES</th>
<th>$\chi^2$ CALCULATED</th>
<th>SIGNIFICANT AT $\chi^2_{critical} = 7.815$ WITH $\alpha = 0.05$ AND THREE DEGREES OF FREEDOM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3.76</td>
<td>No</td>
</tr>
<tr>
<td>Injury</td>
<td>5.55</td>
<td>No</td>
</tr>
<tr>
<td>Right Angle</td>
<td>4.84</td>
<td>No</td>
</tr>
<tr>
<td>Left-Turn Head-On</td>
<td>1.36</td>
<td>No</td>
</tr>
</tbody>
</table>

*If $\chi^2_{calculated} > \chi^2_{critical}$ significant results are found

The results of the statistical analysis for the untreated group indicated that the differences in crash frequencies are not significant for total, injury, right-angle, or left-turn head-on crashes. This indicates that these crash variables did not change significantly and therefore, there were no migration effects from the nearby treatment sites.

The statistical tests were also performed using the chi-squared test of significance for the treated group of intersections indicated significant reductions in traffic crashes for total, injury, right-angle and left-turn head-on crashes. The results of this analysis are presented in Table 5.

### Table 5. Results of Statistical Testing (Chi-Squared Test) for the Treated Group

<table>
<thead>
<tr>
<th>CRASH TYPES</th>
<th>$\chi^2$ CALCULATED</th>
<th>SIGNIFICANT AT $\chi^2_{critical} = 5.991$ WITH $\alpha = 0.05$ AND TWO DEGREES OF FREEDOM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>54.96</td>
<td>Yes</td>
</tr>
<tr>
<td>Injury</td>
<td>26.92</td>
<td>Yes</td>
</tr>
<tr>
<td>Right Angle</td>
<td>30.73</td>
<td>Yes</td>
</tr>
<tr>
<td>Left-Turn Head-On</td>
<td>18.33</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*If $\chi^2_{calculated} > \chi^2_{critical}$ significant results are found
CONCLUSIONS

When site-specific safety treatments are implemented at high crash locations that result in traffic crash reductions, some researchers believe that the past crash experience migrate to neighboring locations. This traffic crash migration phenomenon is evident by increases in crashes at surrounding untreated sites. However, past research does not provide clear cut results.

As a part of a public-private partnership project initiated in 1996 in the city of Detroit, three high crash intersections were studied and low cost safety treatments were implemented in order to reduce traffic crashes. A “before and after” safety evaluation study at these sites revealed that the total crashes and injury crashes were reduced by close to 50 percent. The reduction of right-angle crashes, left-turn head-on, total and injury crashes were also statistically significant. This evaluation study used annual average crashes and injuries using two year’s of crash data for the “before” period and one year of crash data for the “after” period.

Traffic crash analysis for four untreated intersections were also performed using the chi-squared test. The analyses indicated that the untreated group of intersections indicated no significant increase or decrease in total, injury, right-angle or left-turn head-on crashes. Therefore, migration effects were not observed for any of the specific crash types and crash severity tested for these groups.

Based on the effectiveness evaluation of the treated group, the specific safety treatments implemented were successful in reducing the targeted crash types. Specifically, implementing a properly designed all-red interval significantly reduced right-angle crashes and installing left-turn lanes and/or phases at intersection approaches mitigated left-turn head-on crashes. These are specific examples of policy-related modifications that can be adopted by a road agency, with minimal cost of implementation and without any crash migration effect.

ACKNOWLEDGEMENT

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REFERENCES


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Do German Road Restraint Systems Meet European Requirements?

- Test, in accordance with the current European standards, of passive road restraint systems used in Germany -

Federal Highway Research Institute
Uwe Ellmers
Bergisch Gladbach, June 2000
Introduction

Passive restraint systems are systems which restrain and redirect vehicles which leave the road. They are used in Germany in accordance with the “Codes of Practice for Passive Road Restraint Systems” (Richtlinien für passive Schutzeinrichtungen an Straßen – RPS) [1] and are applied in central reserves to divide carriageways and at the edges of roads to protect vehicles against coming off the road and colliding with objects in the roadside area. The number of areas in which road restraint systems are applied has grown in recent years as they have been used to a greater extent at work sites.

Passive road restraint systems such as steel guardrails and concrete crash barriers have been used in Germany since the 50s. While other countries, such as the USA, often use concrete crash barriers, steel systems are more common in Germany. A targeted development and improvement of steel systems took place in Germany in the 60s and 70s. The investigations at that time [2], [3] were based on a large number of crash tests. Crash tests are still used today, after the opening of the European market, to test the suitability of road restraint systems. The requirements which must be met are laid down in European standards.

Every restraint system which is intended to be used on European roads must prove its effectiveness according to the specifications in the standards which are becoming binding in the Member States of the European Union (EU). The performance characteristics of the systems are classified in predefined levels. A fundamental characteristic is the capacity of a system to restrain a vehicle; this characteristic is divided into a total of 6 performance levels according to the types of colliding vehicle i.e. car, bus or heavy load vehicle, and the effective collision energy.

The introduction of these standards is of great consequence for the systems, including those currently used in Germany. Classifying the systems in one of the performance levels is the basis for laying down at national level the areas in which the various systems may be used.

Goals

It was the aim of a research project initiated by BASt and the Federal Ministry of Transport, Building and Housing to create the basis for classifying the systems using crash tests which met the requirements of the standards. The main aim of the project was therefore clear: to test whether the standard steel and concrete systems which are most often used in Germany, and which conform to the RPS [1], also met the European standard EN 1317-2 "Road restraint systems – Part 2: Safety Barriers – Performance Classes, Impact Test, Acceptance criteria and Test Methods" [5]. It would then be possible to classify the systems in the specified performance levels; this would constitute the precondition for retaining and continuing to use the existing systems and for securing the large socio-economic capital which the installed restraint systems represent.

The crash tests to prove the suitability of systems involve considerable financial, staff and technical expense. For this reason, now as in the past [2], [3], tests are mainly restricted to only the standard system constructions.
This investigation had also become necessary as the crash tests from the 60s, which were carried out for the development of the systems used to date, were not conducted according to the test conditions of the European standards. These systems – although they have been used and have proved themselves in the German road network over many years – must therefore prove their effectiveness once more, with regard to the performance levels mentioned above.

National regulations will have to be adapted to these new requirements in the medium term. The timing of the investigation makes it possible to use the results for drawing up national regulations such as the new Codes of Practice for Passive Road Restraint Systems (RPS) which are currently being revised. The findings will also be able to be incorporated at international level into the work of European bodies (CEN) to protect German interests during the elaboration of further standards.

It is also intended to use the crash tests to reveal the qualities and any defects of the current restraint systems in order to gain a more comprehensive picture of the mode of operation and the limits of the systems.

It is also intended that the findings – particularly the negative findings – should be discussed at an early stage with competent parties from industry and to be used by the latter as a basis for improving systems and making new developments. Defects are to be shown through analyses of the behaviour of individual elements of the restraint systems in order to enable constructive alterations to be made and, consequently, the above goal to be reached in the long term with the altered systems.

Systems are regarded as different in this investigation even if they only differ through post intervals or beam profiles. The systems are tested under conditions which correspond to the subsequent practical reality. In addition to the rammed standard design steel systems, the double spacer guardrail in central reserve crossing areas has been included the investigation; this was not previously tested in crash tests. It will therefore be possible to gain fundamental knowledge about the mode of operation and the general behaviour and functioning of the system from the results. This is particularly significant as there are a large number of crossing areas in central reserves on federal motorways.

The EN 1317 European Standards

The CEN (Comité Européen de Normalisation) has been working for some years on the elaboration of European standards for passive restraint systems. These standards lay down standard requirements for the mode of operation of passive restraint systems during the qualification process, i.e. the crash tests; the standards are binding within the European market.
These standards which are at present drawn up by work group 1 of CEN Technical Committee are entitled: „Road Restraint Systems“. They comprise a total of 6 parts:
- part 1: Terminology and general criteria for test methods;
- part 2: Safety Barriers – Performance Classes, Impact Test, Acceptance criteria and Test Methods;
- part 3: Crash cushions; Performance classes, impact test acceptance criteria and test methods;
- part 4: Barrier Systems: Terminals and Transitions – Performance classes, impact test acceptance criteria and test methods;
- part 5: Durability and evaluation of conformity;
- part 6: Pedestrian parapets.

Parts 1 and 2 were introduced in July 1998 and part 3 in May 2000. Drafts exist for the other parts; the drafts have been submitted for formal voting.

Part 2 [5] applies for all types of system which are intended to be used as restraint systems placed longitudinally along the road. It contains - adapted to different areas of application – different levels of requirements with standard conditions for carrying out crash tests on the systems to be tested.

Table 1 shows the possible containment levels and the relevant test types with the crash configurations.

Table 1: Containment levels and crash configuration in accordance with [5]

<table>
<thead>
<tr>
<th>Description</th>
<th>Containment level</th>
<th>Test type</th>
<th>Impact speed [km/h]</th>
<th>Angle of impact [degrees]</th>
<th>Total mass of the vehicle [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal containment capacity</td>
<td>N1</td>
<td>TB 31</td>
<td>80</td>
<td>20</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>N2</td>
<td>TB32</td>
<td>110</td>
<td>20</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td>Higher containment capacity</td>
<td>H1</td>
<td>TB 42</td>
<td>70</td>
<td>15</td>
<td>10000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>H2</td>
<td>TB 51</td>
<td>70</td>
<td>20</td>
<td>13000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td>H3</td>
<td>TB 61</td>
<td>80</td>
<td>20</td>
<td>16000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td>Very high containment capacity</td>
<td>H4a Or * H4b</td>
<td>TB 71</td>
<td>65</td>
<td>20</td>
<td>30000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TB 81</td>
<td>65</td>
<td>20</td>
<td>38000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ TB 11</td>
<td>100</td>
<td>20</td>
<td>900</td>
</tr>
</tbody>
</table>

* Levels H4a and H4b are both valid.
Two tests have to be conducted to be classified in a containment level. A test with high impact energy, i.e. usually with a heavy load vehicle as the test vehicle, is intended to test the maximum containment capacity with the working width (see below) of the system. The second test serves to test the ability of the system to restrain and redirect small vehicles without placing excessive loads on the occupants. This car control test (TB 11) is valid for all levels for which it is required.

The standard lays down not only impact conditions and impact condition tolerances but also requirements regarding the behaviour of the system and of the test vehicle.

Most importantly, the system must ensure that the vehicle colliding with it is restrained and redirected. No important parts of the system may become detached and it must not break or crack. The working width of a system results from adding the maximum dynamic lateral displacement to the installation width of the system. The working width is the space which is required by the system for the respective performance level without endangering areas located behind it (e.g. traffic moving in the other direction). Table 2 shows the 8 possible working width levels.

Table 2: Working width levels in accordance with [5]

<table>
<thead>
<tr>
<th>Working width levels</th>
<th>Size of the working width W</th>
</tr>
</thead>
<tbody>
<tr>
<td>W 1</td>
<td>W ≤ 0.6 m</td>
</tr>
<tr>
<td>W 2</td>
<td>W ≤ 0.8 m</td>
</tr>
<tr>
<td>W 3</td>
<td>W ≤ 1.0 m</td>
</tr>
<tr>
<td>W 4</td>
<td>W ≤ 1.3 m</td>
</tr>
<tr>
<td>W 5</td>
<td>W ≤ 1.7 m</td>
</tr>
<tr>
<td>W 6</td>
<td>W ≤ 2.1 m</td>
</tr>
<tr>
<td>W 7</td>
<td>W ≤ 2.5 m</td>
</tr>
<tr>
<td>W 8</td>
<td>W ≤ 3.5 m</td>
</tr>
</tbody>
</table>

Rolling, tipping and pitching movements by the vehicle due to the interaction between the vehicle and the system are only allowed to a limited extent.

The two parameters Acceleration Severity Index (ASI) [4] and Theoretical Head Impact Velocity (THIV) with Post Head Deceleration (PHD) [4] for the impact severity both apply. They are determined using accelerations measured along the three spatial axes of the vehicle during the impact and using yaw velocity. They allow statements to be made about the reaction of systems on the vehicle occupants and serve mainly to allow systems to be compared with each other. The parameters do not, however, allow any conclusions to be drawn regarding actual injuries, as no bio-mechanical functions exist to date to relate laboratory test results to real accidents. For both the parameters, lower values mean that the impact is less severe for the occupants. Level A of the impact severity levels shown in table 3 is therefore the preferred level.

Table 3: Impact severity levels in accordance with [5]

<table>
<thead>
<tr>
<th>Impact severity level</th>
<th>ASI</th>
<th>THIV and PHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0</td>
<td>9 m/s and 20 g</td>
</tr>
<tr>
<td>B</td>
<td>1.4</td>
<td>9 m/s and 20 g</td>
</tr>
</tbody>
</table>
In order to keep the number of crash tests as low as possible a system which passes the test for one impact level is also regarded as having passed all levels below this. The values recorded for the working width and the impact severity from the tests which have been passed also apply for the lower levels. The values are not adapted e.g. through extrapolation.

If the construction of systems which have already been tested is changed then the systems must be subjected to new crash tests.

The European standards also require restraint systems to have separate tests for all envisaged operation conditions, e.g. in the ground, on paved surfaces and on bridges.

The specifications of these test conditions for restraint systems were laid down with a view to defining a load test for the systems; they are not so much intended to reflect real accident occurrence. This claim is consciously not made by the standard; the tests rather have the objective of approving the systems.

**Test Programme and Execution**

Tests were carried out on the standard designs of the steel systems ESP, EDSP and DDSP and on the 81cm-high concrete crash barrier which had a „New Jersey“ profile; all of which conform to RPS [1] and are used on German roads. Table 4 gives an overview of the investigated systems with the containment levels tested in each case.

The test planning was drawn up based on estimation of the performance of the systems being tested; this estimation was derived from earlier crash tests.

**Table 4: Overview of the test programme**

<table>
<thead>
<tr>
<th>System</th>
<th>Area for use under RPS</th>
<th>Test type under EN 1317-2</th>
<th>tested containment level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP 4.0 (B profile)</td>
<td>edge of roadway</td>
<td>TB 32 + TB 11</td>
<td>N2</td>
</tr>
<tr>
<td>EDSP 2.0 (B profile)</td>
<td>edge of roadway + central reserve</td>
<td>TB 42 + TB 11*</td>
<td>H1</td>
</tr>
<tr>
<td>EDSP 1.33 (B profile)</td>
<td>edge of roadway + central reserve</td>
<td>TB 42 + TB 11</td>
<td>H1</td>
</tr>
<tr>
<td>DDSP 4.0 (B profile)</td>
<td>central reserve</td>
<td>TB 42 + TB 11</td>
<td>H1</td>
</tr>
<tr>
<td>DDSP 4.0+ (A profile)**</td>
<td>central reserve</td>
<td>TB 42*</td>
<td>H1</td>
</tr>
<tr>
<td>DDSP 4.0+ (B profile)**</td>
<td>central reserve</td>
<td>TB 42 + TB 11</td>
<td>H1</td>
</tr>
<tr>
<td>DDSP 2.0 (B profile)</td>
<td>central reserve</td>
<td>TB 42 + TB 11</td>
<td>H1</td>
</tr>
<tr>
<td>81 cm-high concrete crash barrier with “New Jersey” profile</td>
<td>central reserve</td>
<td>TB 51 + TB 11</td>
<td>H2</td>
</tr>
</tbody>
</table>

* Test carried out under commission to the Studiengesellschaft für Stahlschutzplanken (Association for the Study of Steel Guardrails)
** Interval of spacers 1.33 m
The RPS [1] does not differentiate between A profile and B profile beams of steel systems with regard to mode of operation and area of use. Systems with B profile beams were used almost exclusively in the tests as they are more common.

The length of all the systems used for the tests was 60 m with tapering ends at the beginning and end of the system, each measuring an additional 12 m. The only exception was test type TB 51 on the DDSP 2.0, for which the system was installed with a length of 80 m due to the greater impact energy. The terminals of the tapered ends were embedded in the ground. The concrete crash barrier was installed with a length of 70 m. The impact point, in accordance with the specifications in [5], was for all tests approximately 1/3 of the way along the system, measured without the tapered ends.

Common vehicles from various manufacturers were used as test vehicles. For technical reasons it was always the left side of the vehicles which collided with the system. The specifications of standards [4], [5] do not differentiate between a collision with the left and with the right side of the vehicle as there is no fundamental technical difference between these constellations (see fig. 1).

![Test vehicle at the impact point before the test (TB 11) on the cast-in-place concrete crash barrier](image)

**Fig. 1:** Test vehicle at the impact point before the test (TB 11) on the cast-in-place concrete crash barrier

**Test Results and Conclusions**

The tests with higher impact energies (TB 32, TB 42 and TB 51) are decisive for classifying the working width in the containment levels N2, H1 and H2. The car control tests (TB 11) are decisive for classifying the impact severity.
Steel systems

The ASI and THIV/PHD values were within level A for all steel systems tested.

The **ESP 4.0 (B profile)** system successfully met the requirements for car containment level **N2** with a level W5 working width.

The **EDSP 2.0** and **1.33 (B profile)** systems both successfully met the requirements for containment level **H1**. EDSP 2.0 achieved a working width level of W5 and EDSP 1.33 a level of W4.

All three systems can therefore continue to be used, under consideration of the respective working width.

The positive result suggested that the **EDSP 1.33 (B profile)** would also meet the requirements for containment level H2. The result of the TB 51 crash test with a 13t bus as test vehicle which was subsequently conducted was negative in the sense of the standard specifications. The rebound behaviour (box) just failed to meet the specifications. One positive aspect was that the vehicle was restrained and redirected by the restraint system. It remains open whether this positive part of the result can be used so that, with small modifications, the EDSP 1.33 system would be able to pass test type TB 51.

The test analysis indicates that two behavioural patterns are of decisive significance for the relatively large angle of rebound. On the one hand the rear end of the bus passes over the beam system which means that the angle between the longitudinal axis of the bus and that of the system increases. On the other hand the bending sequence of the system showed inconstancies towards the end which was due to the greater difficulty in the posts becoming detached from the post jaws. Making it easier for the posts to become detached from the mechanism could lead firstly to the beam system acting higher up the vehicle so that the rear end no longer passed above the beams and secondly to the lateral deflection of the system being more constant towards the end. This would possibly restrict the vehicle which is guided by the system to a smaller rebound angle which would produce a positive result for the rebound criterion. („box“).

The tests on the **DDSP** system produced differing results which are studied in detail below.

The **DDSP 4.0 (B profile)** (construction method used to date) deflected the 10t heavy load vehicle in the H1 test but was unable to offer the vehicle sufficient resistance and the heavy load vehicle passed right through the system during the rest of the impact sequence. Due to this result two more crash tests on slightly modified DDSP 4.0 systems were conducted. In both tests the system was equipped with an additional spacer (new name **DDSP 4.0+**). The first test was carried out with A profile beams, the second with B profile beams. Both tests were successful so that the modified systems DDSP 4.0+ met the requirements for containment level **H1** with a W6 working width level (see fig. 2). This means that DDSP 4.0 systems must be equipped with an additional spacer for future use.
Fig. 2: Scene from the impact sequence on the DDSP 4.0+ (B profile)

It remains open whether, under TL-SP [6], the successful car control test on the DDSP 4.0 (B profile) system can be used for the DDSP 4.0+ system with an additional spacer, as part 5 of EN 1317 („Durability, Conformity Procedure and Conformity Certification“) has not yet been passed and it is only at this stage that binding regulations will be made regarding the ability to transfer tests. BAST is of the opinion that the successful TB 11 tests on the DDSP 4.0 (B profile) and the DDSP 4.0+ (A profile) should be able to be transferred to the DDSP 4.0+ (B profile) system as the test serves mainly to evaluate the impact severity. This severity was level A in both the tests conducted so that it can be assumed that the value for the DDSP 4.0+ (B profile) will also be within level A, particularly as the system has less flectional strength than DDSP 4.0+ (A profile).
The **DDSP 2.0 (B profile)** system was to be tested for containment level **H2** (13t bus). The performance capability of the DDSP 2.0 (B profile) system was estimated based on the results of earlier tests, in which the double spacer safety barrier had withstood a collision with the parameters of level H2. In the present test the vehicle was deflected by the system but „rode up“ onto the system, i.e. the vehicle’s left wheels (collision side) passed over the system and ended up on top of the system; its centre of gravity did not pass the deflected middle axis of the system. This meant that the system just passed the test.

Due to the unsatisfactory test result, a test at the containment level H1, one level lower down, was carried out as a control test. This is not necessary under the regulations of the standard [5] as higher levels cover lower ones. The test aimed to achieve an unambiguous positive result with an definite classification in containment level **H1**. Contrary to expectations the test was similar to the 10t heavy load vehicle test on the DDSP 4.0 (B profile) system. The system deflected the vehicle but was unable to offer the vehicle sufficient resistance with the result that the heavy load vehicle rode up onto the system during the rest of the impact sequence and the heavy load vehicles centre of gravity passed over the deflected system. This meant that the system did not meet the requirements of the standard [5] for level H1. Contradictory statements can therefore be made regarding the classification of the system based on these two tests.

BASt is of the opinion that this behaviour cannot be regarded as satisfactory. Formally it would be possible to classify the system as containment level H2, but, in view of the negative heavy load vehicle test (TB 42) and with regard to safety, no classification under the specifications of the Euro standard should be carried out as the system was at or even beyond its limits.

Apart from discontinuing to use the DDSP 2.0 (B profile) system and it consequently being necessary to replace the existing systems, considerations could be made on whether the system could be modified by changing from B profile to A profile because of the greater torsional rigidity of the A profile and by installing two additional spacers. This would make it necessary to carry out new crash tests and would mean considerable expense for adapting the existing systems.

The following fundamental behavioural patterns were observed in the tests on steel systems:

- the longitudinal forces acting in the system during the collision, most of which must be absorbed by the beams and their linking joints, were absorbed well by these parts of the system in all tests. They were not the cause for the system failing the tests;
- it was clearly seen that the posts of the systems with dividers or spacers become detached from the post jaws only with great difficulty. One of the reasons for this is the torque which is used to mount the M10 bolts and the large degree of friction between jaw and post. It is far higher than the torque required for these bolts;
- the stability of the joint between the spacers and both the front and rear beams is not sufficient in the standard DDSP to achieve the desired support from the ground. This means that the systems are not able to offer the colliding vehicle sufficient resistance. They can be pressed down and driven over by the vehicle when the wheels are able to hit the rear beam which is on the ground. This mechanism is heavily influenced by the construction of the vehicle. The danger of the system exhibiting this behaviour is particularly acute when the colliding vehicle has large and exposed (i.e. not protected to a significant extent by the vehicle body) wheels (see fig. 3).
Concrete Systems
The first crash test to be carried out in Germany with a heavy load vehicle against a concrete crash barrier - manufactured using the slipform construction method - was a success. The 81 cm-high concrete crash barrier which had a „New Jersey“ profile can be classified as containment level H2. The impact severity measured in the TB 11 control test was above level B. This means, with regard to using the system, that concrete crash barriers, pursuant to the European standard EN 1317-2 [5], may only be used „at specific hazardous locations where the containment of an errant vehicle (such as heavy goods vehicle) is the prime consideration...“. It is the duty of the national regulations to define which points or areas can be classified as particularly dangerous. This has not yet been laid down definitively in Germany.
Table 5 gives a summary of the most important results of the crash tests against steel guardrails and concrete crash barriers.

Table 5: summary of the results of the crash tests on rammed steel guardrails and concrete crash barriers

<table>
<thead>
<tr>
<th>Construction</th>
<th>Containment level</th>
<th>impact severity</th>
<th>ASI and THIV values</th>
<th>dynamic lateral displacement</th>
<th>Working width level</th>
<th>Comment</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP 4.0</td>
<td>N2</td>
<td>A</td>
<td>0.8</td>
<td>3.9 m/s</td>
<td>144 cm</td>
<td>W5</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ESP 2.0</td>
<td>H1</td>
<td>A</td>
<td>1.0</td>
<td>5.3 m/s</td>
<td>115 cm</td>
<td>W5</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDSP 1.33</td>
<td>H2</td>
<td>A</td>
<td>0.8</td>
<td>6.0 m/s</td>
<td>175 cm</td>
<td></td>
<td>failed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDSP 1.33</td>
<td>H1</td>
<td>A</td>
<td>0.8</td>
<td>6.0 m/s</td>
<td>72 cm</td>
<td>W4</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDSP 4.0</td>
<td>H1</td>
<td>A</td>
<td>0.5</td>
<td>4.5 m/s</td>
<td>—</td>
<td>—</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDSP 4.0+</td>
<td>H1</td>
<td>A</td>
<td>0.6</td>
<td>5.5 m/s</td>
<td>110 cm</td>
<td>W6</td>
<td>passed</td>
</tr>
<tr>
<td>A profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDSP 4.0+</td>
<td>H1</td>
<td>A</td>
<td>0.5</td>
<td>4.5 m/s</td>
<td>120 cm</td>
<td>W6</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDSP 2.0</td>
<td>H2</td>
<td>A</td>
<td>0.5</td>
<td>5.8 m/s</td>
<td>131 cm</td>
<td>W7</td>
<td>passed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DDSP 2.0</td>
<td>H1</td>
<td>A</td>
<td>0.5</td>
<td>5.8 m/s</td>
<td>—</td>
<td>—</td>
<td>failed</td>
</tr>
<tr>
<td>B profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Concrete</td>
<td>H2</td>
<td>&gt; B</td>
<td>0.5</td>
<td>5.8 m/s</td>
<td>4 cm</td>
<td>W2</td>
<td>passed</td>
</tr>
<tr>
<td>barrier; 81</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cm; „N J“</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>profile</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary and Prospects

On account of the ongoing European harmonisation, which is also evident in the field of passive restraint systems, the restraint systems most commonly used in Germany, which conform to the RPS [1], were investigated in a series of crash tests so that a report on the effectiveness of the systems tested was available at an early stage. The main aim was to qualify the systems under the requirements of the already existing European standards EN 1317-1/2 [4], [5] and, connected with this, to be able to continue to use the systems without limitation. A total of 17 crash tests with cars, lorries and buses as test vehicles were carried out on a 81 cm high cast-in-place concrete crash barrier with a „New Jersey“ profile and on five steel systems.

The ESP 4.0 (B profile), EDSP 2.0 (B profile) and EDSP 1.33 (B profile) steel systems meet the performance level required under EN 1317-2 [5]. If the new regulations pertaining to vehicle restraint system use, which are currently being elaborated, do not specify any higher containment levels than those applicable to date, these systems can continue to be used under consideration of their respective working width. The 81 cm-high concrete crash barrier with the „New Jersey“ profile was also able to meet, as expected, the level H2 containment capacity. The impact severity, however, exceeded level B so that this system is only to be used at points where preventing the injury of third parties, e.g. through avoiding penetration
of central reserves, is of priority, and if systems of equivalent performance levels with more favourable impact severity are not available.

Despite the fact that the DDSP 2.0 system passed the TB 51 test (H2) and could theoretically therefore be classified as having an H2 containment level, both this test result and the failure in test TB 42 to achieve the H1 containment level were not satisfactory. For safety reasons, use of the DDSP 2.0 (B profile) should be discontinued. The tests do not as a whole show any significantly better performance of the DDSP 2.0 compared with the DDSP 4.0+. In order to make significant progress with systems with double spacers, consideration should be given to the DDSP 1.33 which has not so far been included in the regulations.

The investigation has shown that the one-sided systems function better overall than the two-sided systems. Aligning two of these systems next to each other could therefore be an alternative to two-sided systems. If they are used in central reserves, they are for example also advantageous if there is a difference in height between the carriageways. The construction height, which is of great significance for ensuring that the system functions properly, can then be adapted individually to the respective carriageway. Further advantages are that repairs and maintenance measures can be carried out without disrupting the other carriageway. Additionally the second system provides a certain reserve in safety as the rear of the second system can be regarded as a further separate restraint system, should the first system be passed over by a vehicle. This applies if the systems are installed at a distance of more than 50 cm from one another. If the distance is smaller the rear side of the second system can serve as support for the first system (similarly to the guard rail on bridges when EDSP is used, cf. RPS [1] fig. 56). The size of these respective reserves in safety is difficult to estimate. In order to make a scientifically sound statement the behaviour of the rear side of systems would have to be tested in further crash tests. If required the system could be adapted to the different conditions. This would however result in the system having to be retested regarding its original function, the „normal“ impact with the front side. If this approach were pursued it would be meaningful to also investigate the EDSP 4.0 system which is currently being developed. It has economic advantages over the EDSP 2.0 and the EDSP 1.33 systems.

Crash tests are important for investigating the modes of operation and effect of restraint systems, particularly newly-developed systems. Given the same prerequisites, they also enable comparisons to be made between different systems. The tests portrayed here with the relevant crash constellations constitute critical load cases. This is initially sufficient to bring the system onto the market. The crash tests are of limited significance when the behaviour of the systems in accident occurrence i.e. in operation is also considered. The qualification tests should therefore not lead solely to a general and exclusive characterisation of a system. Accident investigations show from time to time behavioural patterns of systems or vehicles which were not observed in crash tests. It is questionable as to which procedure better depicts the overall nature of this area. This is an open question which must be kept in mind in order to see which procedure is more expedient for enabling safety to be improved through altering systems or developing new systems. The parameters, such as alignment, soil conditions, cross-section location, type and condition of the vehicle, driver behaviour and crash parameters, which are specified by the local conditions, are of decisive influence in this regard.
Bibliography


[5] EN 1317-2 "Road Restraint Systems; Performance classes, impact test acceptance criteria, test methods"; European Committee for Standardization, Brussels 1998

Figures

Fig. 1: Test vehicle at the impact point before the test (TB 11) on the cast-in-place concrete crash barrier

Fig. 2: Scene from the impact sequence on the DDSP 4.0+ (B profile)

Fig. 3: Test vehicle (10t heavy load vehicle) at the impact point before the test (Photograph: G. Lukas; BASi)
Three studies evaluated the potential risks and benefits of an advance brake warning system (ABWS). The system is based on a sensor attached to the accelerator that sends a signal to the brake light whenever the accelerator is released in a sudden manner (0.3 m/s - typical of emergency braking). The signal turns the brake lights on for 1.0 second. If during that time the driver actually brakes, then the following driver perceives a continuous brake light that comes on approximately 0.2 s before the brakes are actually applied (equivalent to the time it takes to move the foot from the accelerator pedal to the brake pedal). If the driver does not brake, then the brake light goes off within 1.0 s (essentially signaling a false alarm). The first study, a field study, showed that the ABWS has a false alarm rate of 25% and that, in general such emergency braking actions are relatively rare. The second study evaluated the additional time that would be provided to the following driver when the brake lights of the car ahead are activated by the ABWS. In a laboratory study, subjects braked in a simulator in response to the onset of the brake lights of the car ahead. The results showed that the critical movement time from the accelerator to the brake pedal (i.e., the added time that a following driver would have to respond) is approximately 0.2 s, and it is not greatly influenced by the level of expectancy. The third study was a computer-based Monte Carlo simulation that evaluated the likelihood of crash prevention due to ABWS under different conditions of speed, road conditions, and headway distances. The results showed that the ABWS should be very effective whenever the headway is under 1.5 seconds. This was true especially under dry road conditions, and regardless of the driving speed. The final study was a fleet study with nearly 400 matched pairs of vehicles – with and without the ABWS - that were tracked for an average of 3 years. The fleet study failed to find a statistically significant benefit of the ABWS. In conclusion, while the ABWS does not compromise safety, its benefits in real world driving are sufficiently small that its incorporation into the vehicle brake-communication system is questionable.

KEYWORDS: Advance Brake Warning, Driving Headway, Brake Reaction Time
INTRODUCTION

In highly motorized countries, rear end collisions typically constitute approximately one quarter of all crashes (National Highway Traffic Safety Administration, 1999). Some efforts directed at reducing these crashes, have focused means to reduce the brake reaction time of following drivers in response to the braking of lead drivers. One approach that relies on shorter perception reaction time of the following drivers to the brake lights of the lead driver is the Center High Mounted Stop Lamp (CHMSL). Three independent early fleet studies conducted in the U.S. showed that the CHMSL reduces 'relevant' rear-end collisions by 50 percent (c.f. Evans, 1991). Evaluations conducted after it installation was required in all passenger cars sold in the U.S. reaffirmed the effectiveness of the CHMSL but with lower estimates of crashes prevented (Farmer, 1996). Other studies have shown that the probability of braking in response to braking by CHMSL-equipped vehicles is higher (Sivak, Post, and Olson, 1981), and brake reaction time to such vehicles is shorter (McKnight and Shinar, 1992) than to vehicles with standard brake lights.

A different approach is to reduce the lag between the lead driver's decision to brake and the onset of his/her vehicle's brake lights; especially in emergency braking situations. The Advance Brake Warning System (ABWS) constitutes evaluated in this study is based on such an approach.

The ABWS evaluated here consisted of a sensor that is mounted on the gas-pedal rod. Whenever that pedal is released abruptly (so that it moves at a speed of 0.3 m/s or more), the brake lights are activated for a duration of 1.0 second. If the driver presses the brake pedal during that 1.0 second interval, the brake lights remain on until the brake pedal is released; otherwise, the brake lights go off after 1.0 second.

Two evaluate the effectiveness of the ABWS three studies were conducted. All of these studies are reported in more details elsewhere. The first was a field study aimed at assessing the prevalence of false alarms: activation of the brake lights by the ABWS without the contingent actual activation of the brakes (Shinar, 1995). A low false alarm rate is a necessary condition of the implementation of the ABWS, since frequent false alarms would dilute the effects of brake lights. The second study was a digital simulation study that was designed to provide probability estimates for the rear end collisions under various circumstances including different speeds, different weather conditions, and different alertness levels (Shinar, Rotenberg, and Cohen, 1997). The final study was a fleet study in which the crash involvement of close to 400 matched pairs of vehicles (with and without the ABWS) was tracked over a period of nearly three years (Shinar, 2000). The purpose of this study was to estimate the expected benefit of the ABWS under real-world driving conditions.
STUDY I – Field study of false alarms generated by the ABWS (Shinar, 1995)

For the ABS to be effective it must satisfy two conditions:

1. A necessary condition that its installation will not in any way compromise traffic safety relative to the present brake light systems and codes. If this condition cannot be met, than its installation should be prohibited.

2. A sufficient condition that its installation should improve traffic safety through a significant reduction of rear-end accidents, relative to present brake light systems and codes. If this condition can be satisfied, then depending on the cost/benefit estimates, its use should be encouraged or even considered as a mandatory standard.

This study addressed the necessary condition: is there an inherent safety problem in the use of the ABW? The potential source for this kind of problem is known as the 'false alarm problem': an excessive rate of activations of the brake lights in response to the ABW sensor without the expected contingent braking behavior. In a previous evaluation of an earlier version of this ABWS, Olson (1988) reported in 28% of the times that the brake light was activated by the ABWS, the driver did not follow the accelerator pedal release with a braking action. However, Olson’s study was done on an earlier version of the ABWS, on a much smaller scale, and in an artificial driving situation.

METHOD

ABWS units and counters were installed in 6 vehicles: two passenger cars with automatic transmission, two with manual transmission, and two pickup trucks with manual transmission. The vehicles were part of a car pool in a communal settlement (a kibbutz), and their users were all licensed members of that commune. They were not aware of the study or of the presence of the ABWS. There were a total of 743 trips made, averaging 83 kilometers per trip.

A hidden electronic event recorder recorded the following five types of events: 1. Total number of braking actions; i.e., each time the driver brakes for any duration. 2. Total number of ABW activations. 3. Number of braking actions whose duration is < 1.0 s. 4. Number of ABWS activations followed by braking within 1.0 s. (i.e., emergency braking) 5. Number of ABWS activations followed by brief braking (< 1.0 s. duration) within 1.0 s.

RESULTS AND DISCUSSION

In total, the six vehicles were driven 61,668 km, and generated 95,394 brake applications, of which 820 - or 0.9 percent - were abrupt enough to activate the ABWS. While brake applications were quite frequent, occurring on the average of 1,547 times per 1000 Km, the rate of emergency braking that activate the ABW system was only 13.3 per 1000 km, and they constituted less than one percent (0.86%) of all brake applications. In contrast, brief braking actions - whether preceded by the ABW light or not – were fairly common, consisting of
approximately ten percent (10.82%)

The total number of brake applications and number of brief brakes (<1.0 sec) applications correlated highly with kilometers driven; r=0.96 and r=0.89, respectively. In contrast, the correlation between kilometers driven and emergency braking (as indicated by the combination of the ABWS+brakes activation), was only 0.34 (not significant at p<.05). Furthermore, the correlation between total braking actions and emergency braking actions also failed to reach statistical significance at r=0.34. Thus, emergency braking seems to be relatively infrequent, quite unpredictable, and not significantly related to kilometers driven. This in fact is what makes it characteristic of 'emergency braking' behavior. It is more likely that the abrupt braking typified by the combined activation of the ABWS and the brakes is due to a combination of extreme traffic situations and possible individual differences in braking styles. The role of individual differences in braking style and its contribution to rear end collisions has been demonstrated by Babarik

There were no significant differences between vehicle types, and so the ABWS was equally applicable to large and small cars, with manual and automatic transmission.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>False Alarms per all ABWS</th>
<th>Brief &lt;1s Brakes per Total Brakes</th>
<th>FA per brief &lt;1s brakes</th>
<th>Emergency Brakes per all Brakes</th>
<th>ABWS w/o brakes per all Brakes&lt;1s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass. Aut1</td>
<td>0.136</td>
<td>0.111</td>
<td>0.004</td>
<td>0.003</td>
<td>0.006</td>
</tr>
<tr>
<td>Pass. Aut2</td>
<td>0.191</td>
<td>0.115</td>
<td>0.030</td>
<td>0.015</td>
<td>0.013</td>
</tr>
<tr>
<td>Pass. Man1</td>
<td>0.277</td>
<td>0.093</td>
<td>0.046</td>
<td>0.011</td>
<td>0.011</td>
</tr>
<tr>
<td>Pass. Man2</td>
<td>0.154</td>
<td>0.096</td>
<td>0.003</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Pickup1</td>
<td>0.268</td>
<td>0.110</td>
<td>0.032</td>
<td>0.010</td>
<td>0.003</td>
</tr>
<tr>
<td>Pickup2</td>
<td>0.490</td>
<td>0.125</td>
<td>0.041</td>
<td>0.005</td>
<td>0.014</td>
</tr>
<tr>
<td>Average</td>
<td>0.233</td>
<td>0.108</td>
<td>0.024</td>
<td>0.009</td>
<td>0.009</td>
</tr>
</tbody>
</table>

The average false Alarm rate was 0.23, and the range for the six vehicles was from 0.14 to 0.49. The rates of different measures are summarized in Table 1. The decision as to what constitutes a low, adequate, tolerable, or high false alarm rate, is not inherent to the rate itself, but
must be derived from other considerations. The primary consideration seems to be a cost/benefit issue of whether the benefit of the correct ABWS activations offset the potential danger of the false alarms. The assumption that false alarms are dangerous stems from the notion that a "high" rate would cause a following driver some indecision as to whether to wait a little in order to decide whether the brake light that has come on is a true braking or just a false alarm. One relevant measure for consideration here is the rate of real brief braking actions; ones that turn on the brake lights for less than one second. In our study this rate was 167 per 1000 kilometers, or 10.8 percent of all brake applications. In Olson's study, though based on much less exposure the rate was higher, reaching 44.6 percent. Thus, from both studies it appears that brief braking actions are quite common. Relative to this frequency the false alarm rate is negligible: approximately one in 50, or 2.4%. Consequently, the rare occurrence of a false alarm would not be noticeable among the many brief brakes already existing in traffic.

STUDY II: Digital Simulation of the ABWS Potential Benefits (Shinar, Rotenberg and Tal., 1997)

In the present study we used a digital simulation to demonstrate the expected savings in frequency and severity of rear-end crashes, given travel speeds typical on different U.S. highways (Godwin, 1992), different roadway conditions (dry, wet, and icy), different inter-vehicle headways (from 0.5 to 2.0 seconds), and different levels of driver expectancy. Since the actual numbers of miles driven under each unique combination of vehicle separations, speeds, roadway conditions, and level of driver expectancy, are not known, the simulation was designed to provide separate estimates for each of the studied conditions.

The simulation used empirically derived distributions of driver perception reaction time for the estimated time from appearance of an obstacle, and empirically derived distributions of brake movement time (the time potentially saved by the ABWS); both from field studies by Olson and Sivak (1986). To nullify the effects of increased alertness - that is typical in an experimental study - we made further adjustments to that data with a multiplicative coefficient empirically derived from field studies by Johansson and Rumar (1971).

METHOD

A digital simulation program was written to evaluate the ABWS effectiveness. The simulation assumed that two vehicles are moving at the same speed in the same direction. When - in response to an emergency situation - the lead driver brakes hard, the car brakes lock and a skidding stop is initiated. The following driver, in response to the onset of the brake lights of the lead car, brakes equally hard to a skidding stop (or collision). When the lead vehicle is equipped with an ABWS, its brake lights come on as soon as the gas pedal is released. When the lead vehicle is not equipped with ABWS, its brake lights come on only once the brake pedal is engaged. The difference between the two is in the movement time from the gas to the brake pedal.

Standard time-distance-speed functions, characteristic of crash reconstruction calculations were applied to both vehicles to calculate distance traveled by time T from moment of maximum
braking, speed at time \( T \), distance traveled to complete stop, and crash severity (defined as impact speed).

The independent variables - factors that could affect the likelihood of collision - included in the simulation were:

1. Vehicle speeds prior to braking. We used speed distributions obtained in a 1988 survey of speeds on two types of U.S. roads (Godwin, 1992): (a) Rural 2-lane roads with 55 mph speed limit, where the average speed was 95.4 km/h, \( \text{sd}=11.0 \text{ km/h} \), and (b) Interstate freeways shortly after the speed limit was increased to 65 mph, where the average speed was 101.1 km/h, \( \text{sd}=9.9 \text{ km/h} \).

2. Inter-vehicle headway. Since empirical studies and roadside surveys have shown that most drivers maintain headways less than 2.0 seconds (Evans and Wasielewski, 1982; Rockwell, 1972; Postans and Wilson, 1983), we chose headways of 0.5, 0.75, 1.0, 1.5, and 2.0 seconds for the simulation.

3. Expectancy and brake response time. Since the total brake response time is the sum of the perception reaction time and the brake movement time, the simulation sampled these two component times from empirical distributions of these times obtained in a field study by Olson and Sivak (1986). Since they also obtained differences in response time between expected and unexpected obstacles, we used different distributions for each and further added a correction factor for alertness derived by Johansson and Rumar (1971) of 1.35.

4. Brake lag time of the vehicles. Braking systems’ lags from 0.07 to 0.15 seconds (TAAR, 1990), and we assumed that the lag times are normally distributed between these limits.

5. Roadway/tire coefficient of friction. We evaluated the ABWS on dry roads (\( \text{cf}=0.7g \)), wet roads (\( \text{cf}=0.25g \)), and icy roads (\( \text{cf}=0.1g \)).

Two dependent measures of ABWS effectiveness were used: (1) number of crashes prevented with vs without the ABWS under identical conditions, and (2) average crash severity, in terms of average \( dV \), with vs without the ABWS. Since in some conditions, on some of the trials the collision was avoided, crash severity on those trials was 0. Consequently, the more collisions prevented, the lower the average severity. Thus, average crash severity is based on all incidents, and not only those ending in rear-end collisions.

There were 120 different combinations of vehicle speeds for the two types of roads (2) X headways between the two vehicles (5) X expectancy/alertness levels of the following driver (2) X coefficients of friction between the road and the tires (3) X the presence/absence of ABWS on the lead vehicle (2). Sixty trials of the simulation were conducted on each of these combinations. Each trial consisted of randomly sampled values of perception reaction time, brake movement time, and brake system lag, from their respective distributions. In all, the data base consisted of 7,200 simulation trials.

RESULTS AND DISCUSSION

The initial analysis of all 7,200 runs, showed that with inter-vehicle headway intervals of
1.5 and 2.0 seconds all collisions were prevented - regardless of the presence or absence of an ABWS. Thus, assuming the following driver is looking at the car ahead when its brakes are applied, he/she has such a safety margin that the ABWS does not add any marginal safety benefits. Therefore the more detailed analyses involved only the 4,320 trials conducted with gaps of 0.5, 0.75, and 1.0 seconds.

Across all conditions, with the variables and levels examined here, the ABWS prevented 82% of all rear end collisions with vehicle headways of 1.0 seconds or less. In contrast, in the absence of ABWS only 27% of the crashes were prevented; indicating that under these situations a driver is 3.0 times as likely to avoid an crash with an ABWS than without one (odds ratio = 3.03).

To examine the interactions of ABWS with the other variables we conducted Chi Square analyses. Alertness and vehicle headway interacted strongly with the presence or absence of the ABWS, while the road condition (coefficient of friction) and the road type (vehicle speed) did not.

The unexpected lack of effect of the coefficient of friction is because it affects both vehicles equally. A situation that is very different from the case of a single car crash. Thus, although the braking of the following vehicle is less effective on a wet or icy road, the lead vehicle is also braking less effectively and consequently the separation between them remains similar across all three conditions.

Driver alertness interacted significantly with the ABWS. The ABWS was more beneficial to an unalert driver than to an alert one. Table 2 shows that without the ABWS, unalert drivers would not have prevented any of the crashes with an inter-vehicle gap of 1.0 seconds or less, while an alert driver could avoid 55% of these crashes. However, an alert driver with the ABWS would be expected to avoid all the rear-end crashes.

Table 2: Percent of Rear-end Crashes Prevented as a Function of ABWS and Driver Alertness

<table>
<thead>
<tr>
<th>Fel! Bokmärket är inte definierat</th>
<th>With ABWS</th>
<th>Without ABWS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unalert</td>
<td>64</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Alert</td>
<td>100</td>
<td>55</td>
<td>77</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>27</td>
<td>55</td>
</tr>
</tbody>
</table>

Chi Square = 323.75, p<.001. No of simulation runs in each cell = 1080. Total = 4320.

Vehicle headway had a most significant interaction with ABWS. As expected and as can
be seen from Table 3, with or without ABWS, the greater the headway, the greater the percent of
crashes prevented. The ABWS' advantage increases as the headway decreases. With a headway
of 0.5 seconds, in the absence of an ABWS none of the crashes were prevented; whereas with an
ABWS even with such short headways 50% of the crashes were prevented. With a headway of
1.0 seconds the ABWS reaches maximum effectiveness (preventing all crashes), while in its
absence 50% of the crashes still occur.
Table 3: Percent of Rear-end Crashes Prevented as a Function of ABWS and Vehicle Headway

<table>
<thead>
<tr>
<th>Headway</th>
<th>With ABWS</th>
<th>Without ABWS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 Seconds</td>
<td>50</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>0.75 Seconds</td>
<td>95</td>
<td>32</td>
<td>64</td>
</tr>
<tr>
<td>1.0 Seconds</td>
<td>100</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Total</td>
<td>82</td>
<td>27</td>
<td>73</td>
</tr>
</tbody>
</table>

Chi Square = 159.87, p<.001. No of simulation runs in each cell = 720. Total  = 4320.

Because it is a continuous measure, severity is a much more sensitive indicator of the ABWS' effectiveness than 'crashes prevented'. A 5-way analysis of variance all main effects except road type were significant at p<.001. The ABWS had two-way significant interactions with driver alertness, road-tire coefficient of friction, and the inter-vehicle headway, as well as all three-way interactions with these variables. These interactions showed that:

1. Crash severity increases with increasing coefficient of friction, thus it is greater on dry roads than on slippery roads.
2. With ABWS on the lead car, an alert following driver has an average crash severity of 0.00 under all road conditions, because all the rear-end crashes are avoided.
3. For an unalert driver, crash severity is 4.0-4.5 times as high without the benefit of ABWS on the lead vehicle as with it.
4. An alert driver benefiting from an ABWS can avoid all crashes even when the headway is reduced to 0.5 seconds.
5. The greatest benefits of the ABWS are for unalert drivers maintaining inter-vehicle separation of 0.75-1.00 seconds. In these cases the difference in vehicle severity is over 3 km/h.
6. Crash severity increases with increasing coefficient of friction and with decreasing headway, so that the benefit of the ABWS increases the most as the headway decreases on a dry road; and increases the least as the headway decreases on an icy road. The maximum decrease in severity with the ABWS - on a dry road, with headways of 0.5-1.0 seconds – was by an average of 4 km/h.

STUDY III: Fleet study of crash involvement with and without ABWS (Shinar, 2000)

The results of the simulation pointed to the clear-cut benefits of the ABWS whenever the driver of a lead vehicle brakes abruptly and the inter-vehicle is less than 1.0s. However, to obtain these benefits it was assumed that: (1) at the moment of braking, the two vehicles are traveling at the same speed, (2) the following driver is actually directing his look at the lead vehicle's brake lights at the time of their onset, and (3) the following driver's response is to brake as soon as
he/she perceives the brake lights. Unfortunately there are no data to indicate the joint probability of these events, relative to all events with rear-end collisions. Furthermore, we do not know the prevalence of headways <1.0 s, and we do not know how often the drivers in rear-end collisions were distracted so that they were not even looking in the direction of the car ahead. Thus, the savings potentials in crash severity and occurrence under real world conditions remain to be evaluated. The purpose of this study was to provide an estimate of the ABWS benefits under real world driving conditions.

In this study 764 government vehicles were tracked over an average period of nearly three years. Half the vehicles in the study were equipped with ABWS, and a matched half were not equipped with ABWS. The objective of the study was to determine whether ABWS-equipped vehicles are involved in significantly fewer relevant rear-end collisions in which they were struck from behind; and if they are, then what is the magnitude of the reduction in rear-end crash risk.

METHOD

The ABWS was installed in 382 vehicles that constituted the ABWS (treatment) group. A matched (in terms of make, model, government agency) group of 382 vehicles without the ABWS made up the control group. Ninety eight percent of all vehicles were 1991-1995 models. Most vehicles were passenger cars, but there were a few small pickup trucks. The drivers were all male government employees, of unknown age (though all were 21 years old or older).

Tracking of crash data was conducted by the Ministry of Transport. Data collection lasted for over three years and the total exposure at the end of the study was 2,188 vehicle-years, with an average of 34.97 months per vehicle. Because some vehicles dropped out of the study before its termination, the average exposure for the treatment and the control groups differed slightly (34.99 and 34.94 months, respectively), but not significantly (t=0.06, p=0.95).

For each vehicle the total number of crashes, and the number of rear-end crashes in which it was struck, were obtained. Rear-end crashes were further classified into relevant and irrelevant crashes. Relevant crashes were those in which the government vehicle was struck from behind while braking or immediately after braking. Irrelevant crashes were those in which (1) the government vehicle was already stopped for a while, or (2) the government driver decelerated or braked gradually rather than abruptly, or (3) the striking driver testified that he/she failed notice the stopping or stopped vehicle ahead. Because the level of detail varied greatly among reports, and because ‘relevance’ was a subjective decision, each case was evaluated independently by four researchers who were ‘blind’ as to whether a vehicle had an ABWS or not. A collision was considered relevant if at least three of the four judges agreed that it was.

RESULTS AND DISCUSSION

There were a total of 142 rear-end collisions, and in all of them the behavior of the striking driver was coded in the accident report as "not keeping a safe distance." In contrast, the struck government driver was not cited for any violation in 96% of the rear-end crashes. Visibility was listed as “optimal” in 90 percent of the rear-end crashes. Only 22 of the crashes
(15%) were injury crashes, and of these 12 collisions had one ‘slight’ injury only. Consequently an analysis of the effects of the ABWS on injuries or injury crashes, or as a function of visibility could not be made.

The total distance traveled by the ABWS vehicles was 44.63 million km and total distance traveled by the control vehicles was 42.75 million kilometers. Average distance traveled per vehicle was 118.7 thousand km for the ABWS cars, and 114.0 thousand km for the control group cars. This difference was not statistically significant (t=1.15, p=.25). A total of 1,722 crashes of all types were recorded for all 764 vehicles: 849 for the ABWS vehicles and 873 for the control vehicles. A Chi Square analysis of the crash frequencies (0-1, 2-4, 5+) of the two groups showed that they were not significantly different (Chi Square = 0.033, p=.98).

The average distance traveled and the average time-in-study per collision was essentially the same for the two groups (t=1.64, p=0.104), but the ABWS vehicles traveled more, with an average difference of 31 thousand km (t = 2.94, p=0.004).

The central focus of this study was to test whether the ABWS-equipped vehicles were involved in fewer rear-end collisions than the vehicles without ABWS. This was assessed for all rear-end collisions, and for relevant rear-end collisions. First, looking at all rear-end collisions, the ABWS group was involved in a total of 75 such crashes and drove a total of 44.63 million kilometers, while the control group was involved in 67 crashes and drove a total of 42.75 million kilometers. When the absolute number of crashes was adjusted for the exposure of each group, the difference between the groups essentially disappeared: 1.7 vs. 1.6 rear-end collisions per million km of travel, respectively.

For a more detailed evaluation of the ABWS, all rear-end collisions were classified as either relevant or irrelevant. Relevant rear-end collisions constitute less than one third of all rear-end collisions (Fisher’s exact test p=0.36). The difference between the groups in the absolute number of relevant collisions was negligible (19 vs. 22 for the ABWS and control groups, respectively). When adjusted for exposure in terms of km of travel, the involvement rate of the ABWS group was slightly lower: 0.43 relevant collisions per million km of travel versus 0.51 relevant collisions per million km of travel for the control group. However, this difference was not significant (Z=-0.51).

CONCLUSIONS AND RECOMMENDATIONS

The three evaluation studies show that: 1. The ABWS does not compromise safety. The rate and the actual frequency of false alarms is very low, either in comparison to the total number of braking actions, or in comparison to the number of brief (less than 1.0 second) braking actions, or in comparison to the miles driven (Shinar, 1995). 2. The ABWS is most effective under dry road conditions, at all speeds, when the headways are 1.0 second or less, and the following driver is attentive to the vehicle ahead (Shinar, Rotenberg, and Cohen, 1997). 3. Under real-world driving conditions, the ABWS has only a marginal benefit in reducing the rate of rear-end collisions (Shinar, 2000). The effect is probably small because the conditions in which the ABWS is most effective are probably rare: requiring a combination of emergency braking with a close following and an attentive driver. Thus, despite the theoretical appeal and the results of the
first two evaluation studies, the fleet study suggests that the ABWS may not be a cost/effective safety device for the prevention of rear-end crashes.

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REFERENCES


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In the United States, the application of Road Safety Audit (RSA) techniques are in their infancy when compared to current practices in Australia, New Zealand, and many other countries. However, within the past two years the Federal Highway Administration (FHWA), some local and state governments, and the Institute of Transportation Engineers have undertaken actions to promote the use of Road Safety Audits as part of an agency’s comprehensive safety program. The objective of this paper is to summarize recent activities to advance the use of Road Safety Audits by state governments, specifically for use at the design stage of project development. This summary is intended to serve as a guide for other countries evaluating the implementation of an RSA program. The paper highlights the development and presentation of an initial two-day pilot workshop designed to advance U.S. state departments of transportation (DOTs) knowledge and use of RSA concepts. To encourage states to integrate RSA practices in their safety programs, the workshop focuses on design stage audits. The heart of the workshop is a practical “hands-on” case study exercise, which examines many facets of conducting an RSA. One issue discussed in-depth is the tort liability implications of an RSA. The experiences in developing and presenting this course and the lessons learned from the pilot presentation are discussed in terms of the implications for other countries in the process of advancing the use of RSAs. The FHWA co-author was primarily responsible for the scanning team’s visit, having seen the value of RSAs on a previous scanning trip identifying safety management practices. The initial findings of this team assessment have identified issues central to adapting RSA concepts for use in the U.S. The authors have been involved in research efforts to examine and overcome these RSA implementation issues. These, as well as brief summaries of the pilot state DOTs findings, are discussed in the paper. The paper also highlights a review of the different stages where audits have been applied and the variations from the traditional RSA approaches that have been tried. The lessons learned from organizing both pilot applications and training programs are stressed.
ADVANCING DESIGN STAGE ROAD SAFETY AUDITS
IN THE UNITED STATES

Introduction

In the United States, the practice of identifying safety improvement needs has been primarily a reactive process. Crash data analysis of high accident locations continues to benefit safety at site specific locations. Crash testing and installation of improved safety appurtenances has improved the survivability of many roadside crashes. Vehicular design improvements and the installation of airbags have also helped. These programs identify high hazard locations and highway safety improvement programs have been generally in response to crash experiences. Recently the concept of safety management systems (SMS) has been introduced to provide a more comprehensive and ongoing program.

A promising new technique for advancing roadway safety programs to the next level in the United States is that of the Road Safety Audit (RSA). The purpose of the RSA is to proactively identify roadway safety issues before a crash history has been established. Incorporating the RSA into the safety management systems of the US Departments of Transportation and to spread success stories of RSAs as a new tool for all local governments will hopefully result in the next level of reductions in roadway crashes and fatalities.

The issues of incorporating the RSA into practice in the United States are not easily solved. In the US the fear of tort liability is widespread. Does identifying a needed safety improvement and not implementing the recommendation increase exposure to tort liability? Mitigating these fears and expanding the use of the RSA into tort liability defenses must be part of the implementation process.

This paper focuses on recent activities to advance the use of RSAs by state governments, specifically at the design stage of project development. Issues that have surfaced in implementing the RSA process and its use as an effective safety tool are identified. It also provides guidance to other countries considering introducing RSAs into their safety program.

What is a Road Safety Audit?

A road safety audit, as defined by Austroads, is “… a formal examination of an existing or future road or traffic project or any project which interacts with road users, in which an independent, qualified examiner reports on the project’s accident potential and safety performance.” (1) The key parts of this definition are: (a) a formal examination, (b) done by an independent, qualified examiner, and (c) restricted to safety issues.
RSAs can be applied at different stages of a project. These include project planning, draft design, detailed design, construction, and in pre-opening of the project. At each stage, an audit focuses on different issues. For example, a planning stage audit evaluates safety issues associated with options such as route locations. A draft design stage audit, sometimes referred to as preliminary design includes the evaluation of general design standards. A final design stage audit would include examining safety issues of specific geometric design features. A pre-opening stage audit is a final check prior to opening the facility to insure that the safety concerns of all road users have been addressed and that hazardous conditions have been eliminated.

A final stage audit, an audit of an existing roadway, is performed on existing facilities to determine if the safety needs of all road users are currently being served. It recognizes that the use of a roadway may change over time. The road safety audit review (RSAR) is a more appropriate term used to define the audit of an existing facility. The RSAR maintains the integrity of the more formal RSA process, but with modifications to allow the technique to be used by local agencies.

Recent History of RSAs in North America

Road safety audits (RSAs) have been used successfully in Great Britain, Australia, and New Zealand for a number of years. In 1996 the US Federal Highway Administration (FHWA) sponsored an international scanning tour to Australia and New Zealand with the objective to “review and document international efforts to enhance highway safety through implementation of safety audit initiatives.”(2) Subsequent to that tour, the interest in Road Safety Audits in North America has increased at a rapid rate. In Canada, the Insurance Corporation of British Columbia has promoted the role of RSAs as a method for lowering casualty loss claims. A Technical Committee of the Institute of Transportation Engineers (ITE) has completed a technical report, “Implementing Road Safety Audits in the U.S.”(3), summarizing recent RSA initiatives. ITE, in cooperation with FHWA, has developed a web site with the address, http://www.roadwaysafetyaudits.org, devoted to RSA activity in North America and within a global context. Several workshops have been held sponsored by the Kansas DOT and other states.

One of the key recommendations of the international scanning tour was that The Federal Highway Administration (FHWA) established a goal to encourage the use of the road safety audit approach during the design phase of roadway development. One of the initial efforts was a two-day workshop sponsored by FHWA and held in St. Louis in May, 1998, designed to encourage states to undertake RSA pilot programs. The workshop included presentations by international professionals who had conducted Road Safety Audits, individuals who had participated in the scanning tour, and representatives from states that had begun RSA pilot programs. FHWA did not set rigorous standards or provide
any special funds to initiate the pilot programs, nor did they provide training other than the materials presented at the workshop. They did indicate that they preferred that audits be conducted during project design stages. Two states had pilot programs underway. The Pennsylvania DOT developed a successful program to implement road safety audits in the design stage and the New York DOT developed a program to integrate RSAs within their pavement overlay program. As a result of this meeting, another eight states agreed to pilot RSAs.

**Results of the Pilot Programs**

The results of the FHWA pilot program are summarized in a draft report prepared by BMI, Inc.\(^{(4)}\) that is currently under review. The document contains the findings and experiences of the eight states that initiated pilot programs along with the results of the audits conducted in Pennsylvania and New York. These included the types of projects audited, the size and make-up of the audit teams, and the costs and lengths of time to complete the audits.

The following observations were provided by the states that participated in the pilot program:

- Management was skeptical
- Lack of a sample audit report and lack of training were hindrances
- Some said they were already doing this in their safety programs
- Several participants said they have no FORMAL process in place to explicitly consider safety
- The documentation in the reports was a subject of concern
- The use of the term “recommendation” was a problem to many

Several conclusions and recommendations were made regarding implementation possibilities including the following:

- RSAs are a specialized tool in the highway engineer’s toolbox
- RSA defines a formalized process for all projects of a given type
- RSA is a formalized process for projects that meet certain criteria

Among the keys to successful implementation were:

- Audit teams should be small - 4 to 5 members
- A safety coordinator is required
- Audits should be conducted early in the process
- Trained auditors are essential
- The term “recommendation” should be avoided
- Audits appear to be more appropriate for 3R, 4R, and capital type projects
- The duration of the audit should be limited
- Maintenance perspectives should be reflected on the audit team
The audit results should focus on “do-able” suggestions
Teams should be composed of experienced members
Implementation is dependent on the support of management
Involvement of new perspectives result in better audits
There is a greater chance for implementation of RSAs in centralized DOTs
The formation of audit teams should consider DOT biases
Cooperation between divisions affects the chance for implementation
Benefits and costs of RSAs must be better documented

The anticipated next steps reported by the states were:

Integrate into design process
Conduct more audits
Use only when appropriate
Create a “safety engineer” position
Wait and see

Pennsylvania has been at the forefront in the application of Road Safety Audits. The Penn DOT Road Safety Audits program was designed to address the following questions:

Will the ROAD SAFETY AUDIT Process ADD VALUE to projects?

Can the ROAD SAFETY AUDIT Process be implemented WITHIN EXISTING RESOURCES?

Will the ROAD SAFETY AUDIT Process DELAY PROJECT DELIVERY?

Fourteen audits were conducted in two districts -District 6 (3) and District 10 (11). Of these, eight were conducted at the draft design stage. The types of projects varied from intersection improvements, to rural 2-lane resurfacing to new roadway construction. The findings of the audits addressed a wide range of improvements. These, of course, varied with the stage at which the audit was conducted.

It was found that audits are low cost - from $2,000 to $5,000 per audit using agency personnel. However, training is an important factor to consider.

If the audits are completed in the early stages, the costs of improvements are low and can be easily be integrated into the project.

The PennDOT experience has proven to be beneficial in many ways. The findings of the audits identified safety improvements that exceeded those that could have been anticipated by just reviewing for standards compliance. Often,
standards only set minimum criteria. By using the RSA process, safety for all road users was achieved.

Additional improvements were identified and incorporated into the projects as a result of a formalized team review. The reports were circulated throughout the agency which led to similar situations being treated in a consistent manner. This “spill-over” into other projects led to additional safety enhancements.

Did the RSAs add value? The Penn DOT experience was an unqualified YES! From the “bricks and mortar” perspective, safety improvements which would probably have been missed were recommended as a result of the process. The quality of the field reviews was enhanced as a result of the application of a formalized process. There was a high degree of self learning among the audit team members and the project designers. The use of experts created a comfort zone for designers. The multimodal input identified safety issues which may have been overlooked in a traditional safety review.

Recommendations from the PennDOT audit experience included the following:

- Buy-in is the key to success. This can not be overstated.
- Cite concerns not recommendations. This is one of the most important issues learned. Recommendations and solutions are too restrictive for the Design Team and could be the biggest cause for tort liability concerns if the recommendation cannot be incorporated.
- A Coordinator is needed to provide leadership, champion the process and keep it on track.
- An interdisciplinary approach is a must if the needs of all road users are to be served.
- Audit team members must have knowledge and skills. This may require training.
- Projects should be selected that are manageable in size and that are anticipated to benefit from an audit.
- A road safety audit and a traditional safety review are different processes. Their use and application should not be confused.
- The team should prepare a formal report. This report should document findings which will be used to undertake corrective actions.
- The report needs to be timely so the short windows of opportunity are not missed and information is not forgotten.
- Differences of opinion will occur between team members. A protocol must be established to resolve these conflicts and to bring the team to a point of consensus.

The New York DOT had already initiated a process that included some elements of the RSAs as a way to add safety auditing functions in their Preventative Maintenance Program (PMP). The SAFETAP program was developed to
consider the inclusion of safety improvements in their resurfacing projects. It was observed that when roads were resurfaced, the number of crashes tended to increase when safety improvements did not accompany the resurfacing. By implementing an audit-type process, safety improvements were identified and corrected at the time of resurfacing.

By having the process in-place, NYDOT was able to demonstrate that safety was not degraded while adding overlays, thus qualifying for federal funding of the resurfacing program. The key element in the NYDOT program was to link the RSA process with an on-going existing program.

Their application could be classified as a Road Safety Audit Review as it focuses on existing roadways. The process is devoted to identification of safety issues, it does use a team concept in the reviews, and findings are reported.

The thrust of the program was on roadside issues, i.e., delineation, guard rail, markings, not on major redesigns. The key element in the NYDOT program was to link the RSA process with an on-going existing program. It was important for the process to be successful that the addition of the RSARs did not have negative impacts or use resources committed to the PMP resurfacing program. This requires buy-in from the participants and responses to the most frequent reactions. In New York it took two years to build a consensus to proceed with a program.

The results obtained from the program exceeded expectations. It is important to note that the success is attributed as much to the establishment and acceptance of a process which incorporates RSAR into an existing program as to the actual measured crash-reduction benefits.

This NYDOT experience illustrates the importance of developing procedures that fit the organization and will lead to substantial crash reductions.

**FHWA Workshop on Road Safety Audits and Road Safety Audit Reviews for state DOTs**

As a follow-up to the pilot program, FHWA sponsored the development of a two-day workshop on RSAs and RSARs for state DOTs. The goals of the workshop are to:

- To develop an awareness of RSAs and their benefits
- To provide participants with information to promote RSAs
- To provide participants with skills and information necessary to implement RSAs.
The initial pilot offering of the workshop was held in August of this year. The direct results of the pilot will be discussed during the Congress. An overview of the course and design approach follows:

The workshop audience is directed towards key issues that need to be resolved in order to develop a successful RSA/RSAR program. These learning keys were designed to emphasize needed decisions within each course module. There are 14 separate modules in the course (see Table 1). The first module keys on the executives or chief executive officers that need to understand the concepts and key issues. In essence, this session is a one hour overview of the course tailored to minimize the time an executive will attend the two-day course. The CEOs attending are also included as participants in this introductory session. An Executive Summary is provided to guide the session (see attached Executive Summary). The CEOs and their key staff provide the initial buy in which is essential for a program and surface their particular concerns. The course has been designed to emphasize a local assessment of the RSA concept.

Table 1: RSA Course Modules

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<th>Session I: Course Overview</th>
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<td>- Introductions</td>
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<td>- Course Goals</td>
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<td>- Focus on New Projects</td>
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<th>Session II: Historically Setting the Stage</th>
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<td>- U.S. Safety Programs</td>
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<td>- Course Objectives</td>
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<th>Session III: Current Safety Practices in Your State DOT</th>
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<td>- RSA/RSAR Implementation Issues</td>
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<td>- Overview of RSA Pilot Results</td>
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<th>Session IV: The Details of RSAs &amp; RSARs</th>
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<td>- Define &amp; Describe</td>
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<th>Session V: Legal Considerations &amp; Implications</th>
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<th>Session VI: Recap of Benefits &amp; Issues of RSAs &amp; RSARs</th>
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<th>Session VII: RSA &amp; RSAR Process</th>
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<td>- When &amp; What to Audit</td>
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Tort liability is an issue central to U.S. safety practice. Using the RSA approach in defense of tort litigation is developed as an integral part of the course. Using summaries of tort law and involving the state DOT attorney general's officers is a separate session. There are no guarantees to preventing tort litigations, however methods using the RSA practice in defense of tort litigation are developed.

Design and planning stage audits are the basis of the course. A planning stage audit concludes the first day pointing out the key issues of safety in general location decisions and the specific issues associated with facility alignment. This case study uses the location of a major interstate highway around a town and was developed based on an actual location decision. This type of major facility, the bypass, is generally the major new design being completed in the U.S. today. The other completely new projects are systems superimposed on the existing facilities and new residential areas. This case study is designed to be completely interactive with the attendees developing responses to the needs for checklists, audit team skills and issues associated with the presentation of audit results.

The design stage audit is the focus of the course during the second day. Attendees are divided into teams and each team completes a design stage audit. Table 2 contains a summary lesson plan for the design stage audit session.
Again the keys are adapting the process to fit within their state operation. A video taped drive through of the project, design plans and reference materials are provided to each breakout team. The instructors interact with the teams only on request. The purpose is to provide as close to a real world experience as possible.

Table 2
DESIGN STAGE WORKSHOP CASE STUDIES

SESSION OBJECTIVES:

1. COMPLETE A TEAM AUDIT OF A DESIGN STAGE PROJECT

2. REVIEW DESIGN STAGE AUDIT MATERIALS PROVIDED AND INDICATE NEEDED IMPROVEMENTS

3. ASSESS THE VALUE OF THE TEAM DESIGN RSA APPROACH

4. RECOMMEND ADDITIONAL AUDITOR SKILLS DESIRED, BUT NOT INCLUDED IN THE AUDIT TEAM

5. PREPARE A VERBAL & WRITTEN AUDIT REPORTS

6. DISCUSSION OF THE FOLLOWING ISSUES:

   • FOR AN IN-HOUSE AUDIT TEAM INCLUDE:
     • ASSESSMENT OF TEAM SIZE & PERMANENT TEAM SKILLS NEEDED
     • ORGANIZATIONAL/LOCATIONAL ISSUES
     • WHEN TO AUDIT? I.E., WHICH PROJECTS? WHICH STAGE(S)?
     • WILL IN-HOUSE AUDITS ADD VALUE TO PRESENT PRACTICE?
     • RECOMMENDED REPORTING PROCEDURE?
       • MEETING BEFORE OR AFTER WRITTEN REPORT
       • FINDINGS OF NEEDED SAFETY IMPROVEMENT ISSUES?
       • INCLUSION OF RECOMMENDATIONS?
       • INCLUSION OF ALTERNATIVES TO CONSIDER?
     • RECOMMENDATIONS FOR RESPONDING TO AUDITOR ISSUES
     • APPROPRIATE ISSUES ASSOCIATED WITH IMPLEMENTING AUDITOR FINDINGS

   • FOR A CONSULTANT AUDITOR INCLUDE:
     • DESIRED ORGANIZATIONAL CONTACT STATUS WITHIN DOT?
     • IDENTIFYING TEAM DESIGN SKILL ISSUES AND REQUIREMENTS?
     • PREFERRED WORKING RELATIONSHIP, I.E. AUDITOR CONSULTANT “ON CALL”? OR RFP FOR AUDITORS FOR EACH PROJECT?
     • NATURE OF THE DESIRED APPROACH—FINDINGS ONLY?, INCLUDING RECOMMENDATIONS?, INCLUDING SUGGESTED ALTERNATIVES?
Each group presents their findings as well as their assessment of a design stage audit. Each team also addresses other general audit issues from the viewpoint of their local practice. The discussion is designed as a self-assessment practice of applying the RSA and/or the RSAR as new safety tools. The concluding session is an evaluation of the course with an ability to assess the actual implementation at future dates within their DOTs. The plans for the course are to make the workshop available upon request. The ideal class would contain one or two state DOTs and the attendees include the CEO decision makers, their key staff and the agency personnel that would either be conducting the audits or contracting with outside auditor consultants.

**International Applications**

Based on the results of the pilot Road Safety Audits performed by states and the experiences gained from conducting the workshop course, it is believed that advances could be made to enhance safety practices in other countries. The pilot projects identified issues and practices that were of prime concern to each of the states. Just as the course was designed to address these issues and to demonstrate how Road Safety Audit concepts could be integrated into existing safety programs, adapting the course to fit specific practice in other countries or provinces within a country could be easily accomplished. Knowledge of existing safety programs and analysis methods and an assessment of tort liability issues would be needed to tailor the course to fit the safety practice in other countries.

The authors believe that applying the results of road safety audits is the next step to reducing the global road causality total. The missing proactive component totally focusing on safety is the key to the future.
Executive Summary

Road safety audits (RSAs) are a proactive approach to improving transportation safety. RSAs have been used successfully in Great Britain, Australia and New Zealand for a number of years. In only the last couple of years, agencies in the United States have begun to focus on RSAs.

What is a road safety audit? Simply put, an RSA is an examination of a future or existing roadway, in which an independent, qualified auditor reports on safety issues. The step-by-step procedure of an RSA can be performed during any or all stages of a project, including planning, preliminary design, detailed design, construction, pre-opening, and on existing roads. For an existing road, the RSA is effectively a review and is discussed as a road safety audit review (RSAR).

Worldwide, the RSA concept has proven to be highly effective in identifying and reducing the crash potential of roadway projects. Globally it is estimated that one million fatalities result from motor vehicle crashes each year. The potential savings—in lives, serious injuries, and property damage—is incalculable.

A few state departments of transportation (DOTs) have begun to incorporate RSAs along with their existing efforts to enhance safety. A program in Pennsylvania has successfully implemented road safety audits in the design phase. In New York, the DOT is integrating RSAs within their pavement overlay program. This practical approach to improving road safety can be implemented in spite of limited resources and the ongoing need to focus on maintenance and operations. To date, 10 DOTs are involved in pilot RSA programs.

Although concerns have been raised that the use of road safety audits would increase an agency’s liability, in fact, just the opposite is true. Implementing a plan to reduce the crash potential and improve the safety performance of a roadway is actually a proactive approach to safety and should be used in defense of tort liability. This is particularly true of RSAs performed in the early stages of a project. Identifying and documenting safety issues on an existing roadway is not an admission of guilt. Rather, it is the first step in a process designed to improve safety. Proper documentation, communication and logical prioritization of an agency’s plan to address safety issues would be difficult to fault.

Road safety audits, adaptable to local needs and conditions, are a powerful tool for state and local agencies to enhance the state of safety practices in the United States. The value of the RSA process in identifying roadway safety issues makes it a potentially important component of any agency’s safety strategy.
References


USING TRANSPORT TELEMATICS IN PREVENTING ANIMAL ACCIDENTS

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1. BACKGROUND

1.1 General characteristics of rural road safety

Finland is quite large country (1000 km long) and inhabited throughout. The road network is spread out. There are some 78 000 km of public roads that are maintained by Finnish National Road Administration (Finnra) and 280 000 km of private roads, but only 20 000 km of streets maintained by municipalities.

We have in Finland a new Road Safety Plan 2005 from The Ministry of Transport and Communications. The plan includes a Traffic Safety Vision, which says:

"No-one will be killed or seriously injured in road traffic"

According this ethical decision there will be only 100 killed people in year 2025.

In 1999 some 440 people were killed in traffic accidents. Every year about 270 people are killed in head-on, single and vulnerable road user accidents - These three types of accidents cover about 80 % of all the fatalities on public roads.

The Ministry of Transport and Communications gives Finnra a road safety goal every year. Last few years the goal has been reduction of 60 - 70 accidents resulting in personal injuries. This goal will be achieved by measures implemented by Finnra or by lowering the speed limit.

The central administration divides the share of the goal left to basic road management among the districts. The districts plan their activity within the framework of set goals, approved lines of action and allotted funds.

1.2 Elk and deer accidents in Finland

Finland has six species of animals in the deer family. The most significant from the standpoint of road safety are the elk (Alces alces), the white-tailed deer (Odocoileus virginianus) and the reindeer (Rangifer tarandus). Because of its weight and size, the elk, in particular, is a significant cause of accidents.
The number and cost of elk and deer accidents have risen again throughout Finland after a slight drop in the beginning of the 1990’s. Table 1 shows that the number of elks in Finland decreased until 1996, but it has risen significantly again during the last few years. The increased number of white-tailed deer particularly in Southern Finland caused a sharp rise in the number of deer accidents. Elk and deer accidents account for approximately 20% of all traffic accidents reported to the police. About 1 500 - 2 800 elk accidents and 1 300 - 1 700 deer accidents occur each year. Fortunately these accidents are less severe than an average accident, and some 7% of animal accidents lead to injuries or death. Still every year 2 - 11 people are killed and some 200 - 300 are injured in these accidents. The cost to society in 1999 was 55 million US$ (4 534 elk and deer accidents). About 4 000 reindeer accidents happen each year, but because of the small size of the animal, usually they are not as serious.

Table 1. Elk and deer accidents in Finland 1992 - 1999.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elk stock in winter</td>
<td>82 000</td>
<td>79 000</td>
<td>70 000</td>
<td>68 000</td>
<td>61 000</td>
<td>79 000</td>
<td>94 000</td>
<td>102 000</td>
</tr>
<tr>
<td>Elk accidents</td>
<td>1 341</td>
<td>1 158</td>
<td>1 409</td>
<td>1 572</td>
<td>1 698</td>
<td>1 792</td>
<td>2 038</td>
<td>2 815</td>
</tr>
<tr>
<td>Deer accidents</td>
<td>731</td>
<td>976</td>
<td>994</td>
<td>1 277</td>
<td>1 361</td>
<td>1 420</td>
<td>1 686</td>
<td>1 719</td>
</tr>
<tr>
<td>Persons killed</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Personal injuries</td>
<td>164</td>
<td>164</td>
<td>208</td>
<td>255</td>
<td>289</td>
<td>223</td>
<td>233</td>
<td>312</td>
</tr>
</tbody>
</table>

2. THE PROBLEM OF ELK ACCIDENTS

2.1 Introduction

Though elk accidents are not ranked among the three major accident types they still form a big problem in Finland. Various measures have been used to reduce the number of these accidents. A new way of using transport telematics to warn drivers when elks are going to cross the road is described in this presentation. The system has been in test use on highway 7 since December 1996 in Uusimaa Region in Southern Finland some 50 kms east of Helsinki. Another similar test site was later (1998) built on main road 5 in South-east Finland. This presentation concentrates on results and experiences collected from highway.

The highest risk for elk or deer accidents occur during the sunset and the few following hours. Middle of the summer, luminous nights in July are most dangerous. The number of elk and deer accident depend on both traffic volume and amount of the elk and deer stock.

Finnra has conducted a survey in which several concentration points of elk accidents on the road network of Uusimaa region were identified. A typical accident spot is located in forest area in low terrain, close to a river bed or edge of field.

Finnra has traditionally averted animal accidents mainly by using warning signs to warn drivers about animals, by clearing roadside vegetation to improve visibility and by building game fences along roads. New methods are continuously being tested, but an efficient universally suitable method has not been found so far.

The easy years in reducing road accidents are gone. The most efficient measures to decrease the number of accidents have been taken. A comprehensive approach is needed to achieve further reductions. This applies also the elk accidents.
Game fences would effectively prevent animals from entering the road if the fences could be made continuous. However, openings need to be made for crossroads. On the other hand fences cause elk to change their travel behaviour thus shifting the problem to new locations. Elk fences have mostly been built along motorways where traffic is heavy and speeds are high.

When designing new roads it is required to arrange natural safe crossings for elks. An analysis of the natural paths for the animals is required. Accident statistics of the elk accidents is also vital information. Proper crossing arrangements are needed to the most safe crossing points. Overpasses and underpasses for the animals can often be built exploiting the natural terrain. However, this is not always possible and the elk crossing concentration points are potential accident prone sections. Other solutions are needed.

### 2.2 Transport telematics used in solution

With the help of transport telematics special road safety measures can be arranged at elk crossing points. The risk for accidents can be kept low by designing the crossing points well. The sites for the openings in the elk fence must have especially good visibility from both directions of road.

Automatically variable elk warning signs were built on highway 7 in Uusimaa region. 1 650 metres long new elk fence was built along highway 7 in 1996 and the new "door" for elk was opened. The detection system observes large animals by the sides of the road. The signs on highway 7 turn on whenever sensors detect an approaching animal. Static warning signs are placed 500 metres and variable fiber-optic message signs 200 metres before the "door" on both sides of the carriageway.

"The door" was about 200 metres wide opening in the elk fence. Totally 20 microwave detectors were installed on both sides of the road on five poles on each side. Poles are situated 25 metres from the edge of the fence and 50 metres apart and 5…20 metres away from the side of the road. The radars face away from the road. There is also an infrared detector on each pole. These detectors are activated through a rain detector. When the rain detector detects much rain the microwave detectors will be connected off and leaving only infrared detectors on (to decrease the number of false alarms). The detection zone of the microwave radars reaches up to 50 metres from the detector and each detector can see horizontally a sector of 60 degrees.

There is also a video camera and recorder in the system, which starts when the alarm system is on.

To monitor traffic volume and speeds there are inductive loop detectors on the road in the middle of the "door".

The system is connected to the Traffic Management Centre of Uusimaa Region.

The variable message signs are turned on when the radars detect a movement. The camera turns in the direction of the alarm given by the microwave or infrared detectors and the video recorder starts recording. The variable message signs are turned off three minutes after the last detection. Three more minutes are recorded on video tape. The alarms are also recorded in the log file of the detection system.

The implementation costs of the warning system were about 90 000 US$.

The system built on main road 5 is similar to the system on highway 7.
3 EVALUATION OF THE EFFECTS

To study the effects of the warning system a survey was conducted on both the test sites. On highway 7 the survey period for the effect on traffic was in January-February and June-July 1997. On main road 5 recording of alarms started in 5th of January 1998 and it lasted until 20th of May 1999 during 202 days.

The effects on drivers were studied on highway 7 (motorway). It was shown that the drivers decreased their speed in all cases in rainy weather and in many cases in darkness when the sign was on. In rainy weather the effect of the sign to speed reduction was 14-15 km/h, but in darkness the effect was only 2-3 km/h.

In daylight and good weather conditions the sign had no or very little effect on drivers.

The reasons for the alarms have been followed continuously on both test sites. On highway 7 the video recordings have been studied. On main road 5 the information was collected from log file of the detection system.

On main road 5 the log file of the had recorded 1816 observations during 202 days. Microwave detectors had caused 30 percentages of the observations and 70 % of the observations were from infrared detectors. Just 71 of all the observations seemed to be possible road crossings of elks.

The video recordings from highway 7 were studied during 3 months May-July in the year 2000. Totally 686 observations were studied. 37 observations were identified as caused by elks or deers. 50 elks and 12 deers were seen on recordings, of which 14 elks and 7 deers were seen crossing the road. In 332 cases it was impossible to identify reason to alarm. Other reasons for false alarms were rain/wind or human/machine/horse.

4 CONCLUSIONS

The costs of elk and deer accidents to society in 1999 were almost FIM 350 million, which is too much. The most effective ways to reduce animal accidents would be to decrease the number of animals and lower driving speeds. Such measures are though very unpopular.

The variable warning signs lowered speeds when weather was poor or it was dark. On good conditions there were almost no effects on driving speeds. There may be many explanations for this. Local people learned that there were many false alarms and during daytime driver's have good view to observe themselves if any animals are on or approaching the road. The system is still rare in Finland and many drivers don't actually understand it correctly. One of the results drawn from a survey conducted, was that more publicity was needed to improve drivers' awarness of the system.

In the future technical operation of the system, sensitivity and operation of detectors have to be monitored more active than they have been done. The quality of log file information has to be informed thus it includes all operational information of the system.

The evaluation of the system has shown that even if many technical improvements are needed, the system has potential in reducing the accidents. Especially in poor weather conditions the alarm caused the drivers remarkably to decrease their speed.
In planning and building this type of systems on elk-accident prone sites on Finnish roads special attention has to be paid to the selection and design of the site and the detection arrangements. It would be ideal if the area of detection were owned by the Road Administration to control the land use of the area.

REFERENCES


ABSTRACT

Strategies for Safe Coexistence of Trees and Highways

by
Kenneth S. Opiela, P.E. Ph.D.
Transportation Consultant
Springfield, Virginia

Trees and utility pole crashes account for more than 8,000 deaths in the U.S. each year. Consequently, this represents a primary element of the AASHTO Strategic Highway Safety Plan. Past efforts have involved limited analysis of the causative factors, but these efforts did not consider all types of roads or rigorously delve into the combinations of roadway, traffic, and environmental factors that may be indicators potential crash problems with trees. This is a complicated problem to solve. Tree grow naturally, roads often evolve to serve higher levels of traffic than imagined, and drivers sometimes fail to understand the risks associated with roadside features. There are valid interests in keeping trees along a highway for aesthetic, noise control, and air pollution mitigation.

New efforts in this area are expected as part of efforts to implement the AASHTO Strategic Highway Safety Plan. The need exists to examine new means to increase the consciousness of the tree crash problem and to implement innovative approaches to addressing it over the longer term. All approaches must be sensitive to the aesthetic and environmental value of trees. A variety of approaches for enhancing the safety of roadsides with trees include removal, moving, replacement, protect/shield, and delineating the trees. The solution may also be found in restricting or calming traffic or managing speed. Of course there are a myriad of possible combinations of these options. It is difficult to make effective decisions because of limited information on the trade-offs (e.g., How many crashes necessitate action? What is an appropriate tree replacement ratio?) A key to the success of these initiatives is establishing a dialogue between the engineering and environmental groups.

The effort will review the issues associated with implementing solutions to the tree crash problem. It will assess agency/organization responsibilities, determine appropriate technical steps to identify target areas where action is needed, define a marketing strategy to build awareness of the problem, establish guidance for getting the various parties involved, and setting a framework for measuring effectiveness. Related matters such as flexible design standards, long term management of tree growth, logical highway beautification programs, and how are potentially hazardous trees on private property addressed. This effort is just getting underway with updated analyses of the characteristics of the problem based upon a detailed crash analyses using the HSIS database.

The paper will present the findings of the crash analyses and provide an overview of the opportunities and constraints identified in the first part of the study. It will offer perspectives on different methods to value the alternative treatments for different types of roads. It will offer suggested criteria and outline processes for assessing the tree risks and selecting appropriate treatments.
Session 8    Vulnerable Road Users e.g. Pedestrian and Bicycles

Vulnerable road users The case of Botswana’s pedestrians
Makghophe

30 km/h in urban areas
Lars Ekman, University of Lund, Sweden
11th INTERNATIONAL CONFERENCE:
TRAFFIC SAFETY ON THREE CONTINENTS
20th-22nd SEPTEMBER, 2000 – PRETORIA
SOUTH AFRICA

TOPIC: VULNERABLE ROAD USERS: THE CASE OF BOTSWANA’S PEDESTRIANS

PAPER PRESENTED BY K. MAKGOPHE
C/O TRAFFIC HEADQUARTERS
BOTSWANA POLICE GABORONE
BACKGROUND

This is a presentation on the pedestrian's situation in Botswana's road system. In order to put it into its proper perspective, there is need to briefly touch on the issue of road safety in general.

One of the tasks of governments in all countries is to ensure the health and security of its inhabitants. In this respect road safety plays an important part. Road accidents claim many victims, and constitute a burden, financial and emotional, both for the society and for those close to the victims and the victims themselves. In developed countries, road accidents usually claim about 2% of the gross national product, in developing countries even more. (Bilprovninger, Gosta Svensson, 1998 P.1).

Road Traffic can be regarded as a system with three interacting basic components: the road and its environment, the vehicle and the human road user. An accident can be regarded as the result of some failure of these components or some malfunction in their interaction. The extent of injury and damage in an accident depends on the situation and type of event, the speed etc. To improve road safety and reduce the rate and severity of accidents, is therefore to reduce the risks for failures and malfunctions in the traffic system as far as possible, and to create an environment that is less aggressive, both along the road and inside the vehicles. The principle is simply to eliminate or at least alleviate risk factors.

Although the world has had motorisation and traffic for about a century by now, there are still quite large gaps in our knowledge about how and why accidents occur. This depends partly on the fact that only a fraction of all road traffic accidents are reported to the Police and partly on the fact that we only occasionally fully investigate and reconstruct the chain of events that ended with an accident. The society can not afford such systematic investigations. Thus we do not know for sure even the proportions between the three basic components as regards their roles as risk factors. Studies carried out in different parts of the world give slightly varying results, but usually have found human factors in nearly 100% of all road accidents,
"road/environment" factors (including daylight and weather conditions) in almost 50% and vehicle factors in 20-25% of the accidents, either as direct or contributory causes of the accident or as factors leading to more serious injury and damage. The studies have also revealed that few accidents have a single, dominating cause. On the contrary, most accidents depend on a multitude of factors, and each one contributes to an increased risk level. Often the accident could have been avoided if only one such factor had been eliminated, regardless of which (Gosta Svensson, 1998 P.1). This also means that there can be several different ways to reduce the risk for a certain type of accidents.

Of course the best potential for improvement would be if all road users could be turned into exemplary, law-abiding, responsible and attentive persons, with perfect perception and presence of mind, especially if it could be done overnight. But it is a well-known fact that although human behaviour can be changed to some extent by training, propaganda and expensive surveillance, more substantial changes of attitudes takes a long time to achieve.

INTRODUCTION

Pedestrians represent a high-risk population since they are unprotected in vehicle impacts. Each year thousands are killed or injured in traffic accidents all over the world, resulting in substantial economic losses due to fatalities and long-term consequences.

1. Statistics for a five-year period i.e. 1995 to 1999 indicate that Botswana’s pedestrian traffic safety situation is not changing for better but for worse. This remains to be the situation despite great efforts made by the Botswana Government through such departments as Road Transport and Safety, Roads, the Botswana Police as well as contributions from the Local Government through city and District Councils (Roads Division) and other Non Governmental Organisations such as private radio stations and newspapers who are stakeholders. The total number of casualties for this period (i.e. 1995-1999) is 5'514 of which 609 are fatalities, 1'655 serious injuries, and 3'287 minor injuries. These figures are derived from Traffic Police Central Statistics Office and include reported cases only. There is a possibility
of there being unreported cases of minor injuries hence the above figures could be more.

2. The following figures and tables indicate pedestrian’s casualty by age, sex, maneuver and injury (fatal, serious and minor).

**Table 1 and 2**

**PEDESTRIAN CASUALTY BY AGE AND SEX**

**Table 1**

**Period = 1995**

<table>
<thead>
<tr>
<th>CASUALTY AGE</th>
<th>CASUALTY SEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
</tr>
<tr>
<td>0-4</td>
<td>54</td>
</tr>
<tr>
<td>5-9</td>
<td>77</td>
</tr>
<tr>
<td>10-14</td>
<td>32</td>
</tr>
<tr>
<td>15-19</td>
<td>45</td>
</tr>
<tr>
<td>20-24</td>
<td>78</td>
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<tr>
<td>25-29</td>
<td>74</td>
</tr>
<tr>
<td>30-34</td>
<td>35</td>
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<td>35-39</td>
<td>39</td>
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<td>40-44</td>
<td>17</td>
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<tr>
<td>45-49</td>
<td>16</td>
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<td>50-54</td>
<td>11</td>
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<tr>
<td>55-59</td>
<td>10</td>
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<tr>
<td>60-64</td>
<td>3</td>
</tr>
<tr>
<td>65-69</td>
<td>4</td>
</tr>
<tr>
<td>70-74</td>
<td>4</td>
</tr>
<tr>
<td>&gt;75</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>502</td>
</tr>
</tbody>
</table>
Table 2
Period = 1999

<table>
<thead>
<tr>
<th>AGE</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>0-4</td>
<td>80</td>
<td>39</td>
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</tr>
<tr>
<td>5-9</td>
<td>149</td>
<td>115</td>
<td>264</td>
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<tr>
<td>10-14</td>
<td>61</td>
<td>79</td>
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</tr>
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<td>20-24</td>
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</tr>
<tr>
<td>&gt;75</td>
<td>5</td>
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</tr>
<tr>
<td>Total</td>
<td>844</td>
<td>630</td>
<td>1474</td>
</tr>
</tbody>
</table>


The other three tables (1996, 1997 and 1998) not indicated here also show a steady increase of casualties from 1995 to 1999 as indicated above.

Besides the general steady increase other lessons learnt from tables 1 and 2 is that, the worst affected age group is 5-9 years.

- Productive population i.e. 15-45 years, is also badly affected.
- Young males are badly affected than females of the same age group, probably due to socio-economic factors.
Table 3

PEDESTRIANS CASUALITY BY AGE AND SEX

Period = 5 years (1995-1999)

<table>
<thead>
<tr>
<th>CASUALTY AGE</th>
<th>CASUALTY SEX</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>70-74</td>
<td>25</td>
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<tr>
<td>&gt;75</td>
<td>39</td>
</tr>
<tr>
<td>Total</td>
<td>3'230</td>
</tr>
</tbody>
</table>

(Source: Traffic Headquarters Gaborone: Accident Statistics)

The above figures are a composite of the 5 year period (i.e. 1995-1999) indicating pedestrian casualty by age and sex.
PEDESTRIAN MANEUVER AND CASUALTY INJURY

Period 1995-1999 (5 years)

<table>
<thead>
<tr>
<th>Maneuver</th>
<th>Fatal</th>
<th>Serious</th>
<th>Minor</th>
<th>Total</th>
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</thead>
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<tr>
<td>Walkr</td>
<td>61</td>
<td>137</td>
<td>279</td>
<td>477</td>
</tr>
<tr>
<td>Cross</td>
<td>417</td>
<td>1146</td>
<td>2077</td>
<td>3’640</td>
</tr>
<tr>
<td>Play</td>
<td>5</td>
<td>53</td>
<td>94</td>
<td>152</td>
</tr>
<tr>
<td>Footp</td>
<td>20</td>
<td>55</td>
<td>147</td>
<td>222</td>
</tr>
<tr>
<td>Others</td>
<td>106</td>
<td>690</td>
<td>690</td>
<td>1060</td>
</tr>
<tr>
<td>Total</td>
<td>609</td>
<td>1’655</td>
<td>3’287</td>
<td>5’551</td>
</tr>
</tbody>
</table>


Walkr - Walking on the road
Cross - Crossing the road
Play - Playing on the road
Footp - Walking on the footpath

3. The above figures are a composite of the 5 year period (i.e. 1995-1999) showing pedestrian maneuver and casualty injury.

A closer look at all the above figures and tables reveals the following;

- Pedestrians of the ages 04 to 39 years are the most affected and the majority of them are young males between the ages 04 to 29 years.

- Pedestrian maneuver indicates that the greatest number of casualties are those hit whilst trying to cross the road i.e. roughly 3’640 out of a total of 5’551 over the five(5) year period which is about 65.6%.
4. There are several explanations for the above state of affairs. To start with, it is not surprising to find that the majority of casualties are young (04 to 39 years) because most of Botswana's population is young, roughly 50% of the population is below 20 years. So in simpler words, there are more young pedestrians in the streets of Botswana than any other group, hence the higher casualty figures in this category. Secondly the young are the most active and mobile in our society. Further more, the very young pedestrians (children of the ages 04-09) have the least ability in our road traffic system due to lack of maturity and ability to adapt themselves to traffic condition for development reasons. Most of the fatal road accidents involving pedestrian children are said to relate to the "dashing out category". The most famous Police statement being;

"THE CHILD SUDDENLY DASHED ON TO THE ROAD AT CLOSE RANGE WHEN MOTOR VEHICLE WAS TOO CLOSE HENCE COLLISION OCCURRED". In almost all these accidents a very strong social incitement is to be found. This child is on his way to somewhere, from somewhere, in play together with others, or on an errand, which means that the child is concentrating on other things rather than traffic.

5. Thirdly, the reason why a lot of pedestrians are hit whilst trying to cross the road is that accidents occur frequently in town/city (build-up areas) and pedestrians crossing a street are often struck from the side in a more or less perpendicular direction by the vehicle front. Ashton (1975) and Otte (1989) studied the distribution of primary contact and found that in 80-90% of the cases the pedestrians were hit from the side. In Botswana, such studies have never been undertaken, but it seems Ashton and Otte theory is right because Police daily accident report forms indicate that most of the injuries are on the sides, and this is only natural as proved by the huge figure of 3'640 because they are hit when crossing. Danner et al.(1978) reported that pedestrians were primarily impacted by the car front (68.5%), followed by the car side (28%). The other reason might be that, when faced with this kind of a situation, the individual pedestrian runs for his/her life and common
sense dictates that one runs past the vehicle not infront of the vehicle, hence they are hit from the side.

6. Jikuang Yang and Per Løvsund in their paper; **Review of pedestrian protection from vehicle impacts**, argue that the causes of pedestrian injuries and injury mechanisms are complicated to determine since accidents may involve both impact with the car and with the road surface. One possibility to find the causes could be by in-depth field studies (Ashton, 1975; Appel et al, 1978, Douher et al., 1979) vehicle impact has been confirmed to be the main cause of fatal and severe injuries (Ashton and Mackay, 1979). The secondary pedestrian-ground contact may of course contribute to severe injuries, depending on which body area hits the ground first and at which velocity. They further assert that the main factor to measure the severity of vehicle-pedestrian impacts is the impact speed. In approximately 70% of all the crashes, the driver braked before the pedestrian was hit (Ashton, 1978, Appel et al, 1978, Maclaughlin et al 1987). Thus most of these crashes occurred at an impact speed lower than 50km/h. Pedestrians struck at impact speeds less than 25km/h usually sustain only minor injuries, serious injuries occur at roughly 40km/h whilst at speed greater than 55km/h the pedestrians are most likely to be killed (Ashton, 1982).

7. Briefly what Ashton and others are saying is that speed kills and the speed level sets the safety level. In Botswana, the pedestrian injury and location of accident clearly indicate that drivers disregard speed levels even in build up areas. What is interesting is that statements made by most of the drivers involved in accidents indicate that they saw the pedestrians prior to collision yet they failed to take a decisive action to avoid the collision. This is a clear indication of the fact that the drivers, especially the new and young, fail to see the correlation between speed and collision severity.

8. The other factors which contribute to the rise in pedestrian accidents in Botswana include;
(a) **Inadequate provision for pedestrians in the road network in rural and urban centres.** When one takes a look at most of the roads in Botswana especially in older settlements it becomes clear that the then road engineers and planners did not take into consideration the issue of pedestrians. Taking Gaborone City as an example, the set up at the main mall gives one an impression that it is a city which was planned for only, at the least 5 000 people because the available pedestrian side walks are thin and squeezed in by buildings hence they are failing to serve their true purpose.

In 1983 SweRoad was engaged to do a consultancy on road safety and one of the observation that stood out clearly in their report was the fact that the road infrastructure did not cater for pedestrian hence the conflict. In an ideal traffic situation pedestrians should always be provided with their own facilities so that the conflict between them and motorists in minimised.

Motorists do not regard pedestrians as fellow road users but trespassers and thus are not prepared to share the available road space with them. Most unfortunately in some instances pedestrian themselves do not help the situation by failing to comply with simple rules that regulate their conduct on the road. The resultant effect is that in this conflict pedestrians come out the more bruised.

(b) **Land use planning** – this is manifested by situations whereby some service centres like shops, schools etc are situated on opposite streets and pedestrians are forced to always cross the roads to such centres. This further put the pedestrians at a higher risk of being run-down by vehicular traffic while trying to cross such roads. What this means is that at times even when pedestrians are fully aware of the dangers of regularly crossing the road they have no option because of the situation they find themselves in. Their physical location near major roadways is itself a source of danger. A typical example in Gaborone City is the Western by-pass road where it passes
between Gaborone West residential area and block five(5) residential area. Most of the schools and shops are on the side of Gaborone West and on daily basis pedestrians cross this road which is just like a highway right in the middle of a build up area. There is not even a single pedestrian crossing on this road, and even if there was such a crossing, it would be suicidal to use because the road is four-laned, running for a distance of 2kms through the two residential areas with no speed calming facility of any kind. At the point where it passes through these residential areas speed control by the Police is almost impossible to carry out because the four lanes are divided by a physical barrier separating traffic from opposite directions and the sides are paved with no lay byes. A speed trap operation in this kind of set up can create more chaos instead of preventing accidents. To start with, without lay byes there is no how the Police would take the violating motorists off the carriage way. Secondly the slightest delay in traffic would result in congestion or even nose to tail collisions due to high speeds.

(c) **Pedestrian road use education/information** is also not well disseminated to road users especially children who constitute a major portion of pedestrians. The only available information about road safety they come across is road signs and their meaning, and this is very far from changing their road safety attitude. Furthermore there is a problem of pedestrians failing to use designated crossing places wherever such facilities are in place. This is a consequence of several factors and among others is the fact that most of these facilities do not suit the needs of pedestrians yet they are supposed to be created for them. A typical example is the pedestrian overhead bridge linking Gaborone Main Mall (C.B.D.) and Gaborone train and bus station which was underutilised immediately after its completion. Pedestrians preferred to go underneath the bridge and a great number of them were seriously injured and some killed by passing motor vehicles until the Police intervened and physically forced pedestrians to use the bridge. A closer look at the situation revealed the fact that when the bridge was
constructed it was taken off the original footpath which led directly to the bus rank and now the new bridge had increased the distance to the bus terminal. Secondly the bridge has many stairs and climbing it is a struggle for the old, weak and sick hence their preference to go underneath it and risk being knocked down by motor vehicles.

(d) **Driver competency and attitude** – In Botswana there is a multitude of driving schools run by multifarious individuals. What this means is that variation from standards set by the department of transport as regards driver training is bound to be rampant. To start with, the personnel at the department are not enough to monitor and control these schools. The only control they have is that of registration and this helps as far as knowing the number of such schools and does not guarantee compliance to rules and regulations set by the department. Secondly, some of the instructors do not meet the required standards to act as trainers. This is mainly because of the fact that the owners of these schools are employed elsewhere, either in the civil service or private sector and their primary goal for running such schools is to supplement their normal salaries, hence they can not afford to pay qualified instructors and they resort to unqualified instructors whose renumerations are easily negotiated. Consequently, we find multifarious breeds of drivers on our roads who contribute massively to pedestrians death and injury.

(e) **Inadequacy of the ROAD TRAFFIC ACT – CAP. 69:01**

**BOTSWANA LAWS** – Botswana Road Traffic Act is failing pedestrians in so many ways and it is failing to discourage dangerous and reckless drivers. The only few sections in the act dealing with pedestrians only go as far as stating how pedestrians should conduct themselves whilst on the road. Section 96 of the Road Traffic Act Cap. 69:01 reads as follows:-

---

11
1. Whenever a side-walk or footpath abuts on a road, a pedestrian shall not walk on such road except for the purpose of crossing from one side of such road to the other or for some other sufficient reason.

2. A pedestrian on a road which has no side-walk or footpath abutting on it shall walk as nearer as is practicable to the edge of the road on his right hand side so as to face on-coming traffic on such road.

3. A pedestrian shall not cross a road without satisfying himself that the road is sufficiently free of on-coming traffic to permit him to do so safely.

4. A pedestrian when crossing the road, shall not loiter thereon but shall proceed with due dispatch.

5. A pedestrian on a road shall not conduct himself in such a manner as to or as is likely to constitute a source of danger to himself or to other traffic which is or may be on such road.

In my view this is a very good piece of legislation which requires pedestrians to exercise some sense of responsibility when using the road unfortunately it does not cater or provide for young pedestrians who are still new to the traffic environment. Not only that but drivers also tend to expect every pedestrian to exercise due care irrespective of age. Drivers should recognise that unlike pedestrians they go through some form of formal training in order to qualify as drivers and so they should always anticipate the movement of pedestrians and be ready to avoid hitting them. After all everybody is a pedestrian at some stage. Secondly our accusatorial criminal justice system which requires quite a number of witnesses and proving a case beyond reasonable doubt, delays punishment and securing a conviction is almost unthinkable especially when a pedestrian is knocked on the middle of the road.
For example, out of the total cases where motorists were found to be at fault only 10% of the cases were successfully prosecuted. It is even becoming a culture that everytime a pedestrian dies it is seen as a “pure accident” irrespective of the circumstances. The thinking is that there was no intent and because he/she was killed by a motor vehicle the driver is not a killer. Unlike in a murder case which our society views seriously, the killer driver after a few hours of Police paper work he/she is released back into the streets to wait for court proceedings if he/she is charged, and maybe to kill again because during this period of waiting the accused persons are still in possession of their drivers licences and they are at full liberty to drive. It could even take up to two years before their cases are heard in courts. It is hoped this situation would improve because the Road Traffic Act is currently under review.

9. In addressing the above problem, the government of Botswana has put in place specific measures aimed at reducing the number of pedestrians who get killed and injured on our roads. Some of these measures are as follows;

- Separating pedestrians from motorists by construction of side walks/foot pavements.
- Massive Road Traffic Act Enforcement by Traffic Police.
- Opening up children traffic schools.
- Construction of pedestrian overhead bridge and under passes.
- Increasing street lighting.
- Installation of signalised crossings.

10. The Swedish Professor Olof Gunnarsson argues that planners, architects and engineers together with other professionals must find ways to create a city culture in which walking/biking must be seen as both natural and necessary. Car-free or walking, biking-friendly areas should be implemented in the city centres and in residential areas.
Speed control and traffic calming measures should be introduced over the whole urban area to ensure safety. (Gunnarsson 1995).

11. Gunnarsson further indicated that a program to promote walking and satisfy the needs of pedestrians is necessary and should be promoted. An outline of measures that present themselves for consideration are as follows:—

- Variety in housing and city functions, and proximity to work and service should be provided.

- Walkways and pedestrian areas should be continuously connected, comfortable, and free from hazards and risks, as well as free from air pollution.

- Pedestrian areas should be made interesting and attractive by varying the environment, places where people can meet on foot and enjoy the city atmosphere.

- Safe and comfortable walkways, environment-friendly and affordable public transport service should be offered.

- Street furniture should be available to disabled persons, e.g. seats for resting.

- Information should be given at key points in an easily understandable way.

- Walkways and streets should be maintained well and illuminated for safe and secure walking.

12. All the above measures are good and would be a welcome development in the fight against pedestrian accidents. But for third world countries like Botswana most of these measures are still in the "pipeline" and by the time they are put in place a lot of damage would have been done. The major problem is budget constraints and accidents are competing for recognition with other issues of national concern such as the AIDS pandemic, environmental and land issues.
Nevertheless, the mere fact that authorities are conscious of the pedestrians peril on our roads gives one hope that there is some light at the end of the dark tunnel and one day all of us will play our specific roles rightly at the right time and bring pedestrian suffering to an end on our roads.

**CONCLUSIONS**

It is a fact that alertness, perception and presence of mind are still about the same as thousands of years ago, and are not likely to improve very much in the next thousands. Nevertheless, we must always keep in mind that road safety is nothing we can leave to others, we are all road users, and must take our responsibility for not only owning safety, but also for not creating dangers for our fellow road users. It is also a well-known fact that the modern society cannot function properly unless a large number of people are able to transport themselves in their own vehicles. A very important part of the work to improve road safety is therefore to simplify the task of the driver by making the road and the vehicle safer and easier to use, hence safety for all road users.

It is worth noting that the majority of the examples given here are mostly referring to the situation in Gaborone the capital city of Botswana. This makes it appear like the situation in Gaborone is common all over the country, but this is not the case. The majority of the pedestrians are hit in Gaborone and the numbers decrease as you move down to small towns and rural areas, for the simple reason that human population and vehicular traffic also decreases when one moves away from Gaborone and other major urban areas like Francistown, Lobatse, Jwaneng and others. But the situation of pedestrians is generally the same all over the country as shown by lack of pedestrian facilities both in urban and rural areas.

Last but not least this paper does not claim to be exhaustive or an authority on pedestrian accidents and issues in Botswana, but it is a Botswana Traffic Police perspective and it seeks to bring to your attention the fact that even in this era of computer age and globalization there are still some places on the face of this globe/earth where pedestrians are still suffering and vulnerable.
BIBLIOGRAPHY


ABSTRACT

The City Council of Pretoria identified a need to set up a traffic control plan and road safety plan for Maunde Street in Atteridgeville. Maunde Street is an important east west corridor serving Atteridgeville and carries relative large volumes of vehicles and pedestrians.

The need to set up this plan originated from actions by Gautrans and the Greater Pretoria Metropolitan Council to address road safety in the area. A business plan was prepared to address especially pedestrian safety in the Metro Area with the objective to reduce pedestrian fatality rates with 30%, over the next five years.

Specific problems identified along Maunde Street include a high percentage of accidents happening at night (35%), high vehicle / pedestrian conflict between pedestrians and taxis as well as roadway verges that are not properly developed. Illegal movements by vehicles - vehicles stopping anywhere along the road and in intersections, together with jay walking by pedestrians - were identified as problems.

Specific actions were taken during the project to involve the community to identify problems and to assist with the development of solutions. A bus tour through the area (the total section investigated was 3,7 km) was done to allow representatives from the community to show problem areas.

The solutions proposed to address the problems consist of the three aspects - engineering, education and enforcement. A range of engineering related physical measures was investigated and recommended, including additional raised pedestrian crossings, providing vertical kerbs around intersections, pedestrian walkways, paving of the complete area surrounding intersections, improved street lighting and additional taxi bays.
1. INTRODUCTION

Maunde Street is an important east-west arterial serving Atteridgeville and the new extensions of Atteridgeville. The location of Maunde Street is shown in Figure 1. Maunde Street is a typical Township Street - a long straight street that has a mobility function, but has direct residential access, no paved sidewalks, many pedestrians and many taxis.

The need to conduct a road safety investigation in Maunde Street was identified and the City Council of Pretoria launched a study with the following objectives:

- evaluate the correct usage of existing traffic control measures,
- determine the extent, type and cause of accidents along Maunde Street,
- compile a strategy for the management of existing and future implementation of traffic control devices along Maunde Street,
- evaluate the applicability of existing public transport facilities along Maunde Street,
- identify locations for possible future public transport facilities, and
- improve pedestrian safety along the street.

The purpose of the traffic control plan and road safety investigation is to evaluate the existing traffic control measures and pedestrian facilities in order to determine the effectiveness thereof.

The methodology followed consisted of obtaining all the relevant status quo data - traffic counts, accident statistics, previous planning studies, etc. Extensive field observations were done and intersections were analysed. Liaison with the community also took place in the form of a meeting and a bus tour through Maunde Street as well as meetings with ASTRASA (Atteridgeville / Saulsville Road Safety Forum). This was followed by detail analysis and development of solutions.

2. STATUS QUO

2.1 Geometry

Maunde Street has a road reserve width of 25m. The road has one lane per direction
of 3.7 m wide and a pedestrian walkway on the northern side of the road of 1.5 m wide. Taxi and bus bays of approximately 2.5 to 3.0 m wide are provided at regular intervals.

There is no paving or grassing of the sidewalk other than where the pedestrian walkway is provided. The spacing between intersections is shown in Table 1 below. The typical sidewalks and intersections are shown in Photos 1 and 2.

**TABLE 1: SPACING BETWEEN INTERSECTIONS (STOP CONTROL)**

<table>
<thead>
<tr>
<th>From Street</th>
<th>To Street</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makaza</td>
<td>Mphalane</td>
<td>345</td>
</tr>
<tr>
<td>Mphalane</td>
<td>Ntsu</td>
<td>355</td>
</tr>
<tr>
<td>Ntsu</td>
<td>Sekhu</td>
<td>730</td>
</tr>
<tr>
<td>Sekhu</td>
<td>Hlahla</td>
<td>480</td>
</tr>
<tr>
<td>Hlahla</td>
<td>Magombane</td>
<td>490</td>
</tr>
<tr>
<td>Hlahla</td>
<td>Moloantoa</td>
<td>410</td>
</tr>
<tr>
<td>Moloantoa</td>
<td>Khoza</td>
<td>915</td>
</tr>
<tr>
<td><strong>TOTAL LENGTH</strong></td>
<td></td>
<td><strong>3725</strong></td>
</tr>
</tbody>
</table>

### 2.2 Traffic Demand

The traffic demand on Maunde Street, between Hlahla- and Sekhu Streets is approximately 830 vph (both directions) during the AM peak hour and approximately 940 vph (both directions) during the PM peak hour.

### 2.3 Pedestrians

Maunde Street carries relative high pedestrian volumes. The main reasons for the high pedestrian volumes are:

* the relative high density housing with direct access onto Maunde Street,
* the fact that Maunde Street is a public transport route,
* the presence of schools both sides of Maunde Street.

Pedestrians, when walking parallel to Maunde Street, does not pose a serious traffic safety problem. Crossing pedestrians, especially "jay-walking" pedestrians is a high risk and measures needed to be taken to improve their safety.

The pedestrian volumes crossing Maunde Street range from 200 pedestrians per hour to 400 pedestrians per hour; pedestrians walking along Maunde Street range from 100 to 200 pedestrians per hour.
2.4 Public Transport

Maunde Street is a major public transport route carrying relative high volumes of buses and taxis. At present, there are several taxi lay-byes located on the northern and southern sides of the road.

Bus volumes range from 30 to 45 buses per hour per direction, taxis range from 120 to 300 taxis per hour per direction. The modal split was determined on different sections of Maunde Street and is shown in Table 2 below.

<table>
<thead>
<tr>
<th></th>
<th>East of Mphalane</th>
<th>East of Moloantoa</th>
<th>East of Mosalo</th>
<th>AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>6.50%</td>
<td>8.00%</td>
<td>4.50%</td>
<td>6.33%</td>
</tr>
<tr>
<td>Taxis</td>
<td>67.00%</td>
<td>34.00%</td>
<td>28.50%</td>
<td>43.17%</td>
</tr>
<tr>
<td>Cars</td>
<td>25.00%</td>
<td>57.50%</td>
<td>64.00%</td>
<td>49.00%</td>
</tr>
<tr>
<td>Heavy Vehicles</td>
<td>1.00%</td>
<td>0.50%</td>
<td>3.00%</td>
<td>1.50%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.00%</td>
<td>100.00%</td>
<td>100.00%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

2.5 Accident Statistics

Accident statistics for Maunde Street was obtained from the Pretoria Traffic Department. The statistics was in varying formats and for different periods, some of them overlapping and not all with the same detail information. The statistics are shown in Tables 3 to 7 below.

The following conclusions can be made from the accident statistics:

- Three main types of accidents occur, namely head to rear end collisions, accidents with pedestrians and sideswipe accidents.
- The intersections where the highest frequency of accidents occur, are also the intersections with the highest traffic volumes.
- In the 29 month period for which data on the grade of accidents is available, 4 fatalities and 25 serious injuries were reported. The frustration expressed by the community relates well to these statistics.
- The frequency of accidents is higher during the off peak period, when speeds are probably higher due to lower traffic volumes. It is important to note the high frequency of accidents at night between 18:00 and 06:00, when 35% of accidents occur. This is an indication that the lighting is inadequate, which was confirmed with field surveys.
- The location of accidents with pedestrians indicate that “jay walking” - pedestrians crossing the street uncontrolled between intersections - is the highest cause of pedestrian accidents. It is an indication that pedestrians should be encouraged to stay on the side walk.
### TABLE 3: FREQUENCY OF TYPE OF ACCIDENTS

<table>
<thead>
<tr>
<th>Type of Accident</th>
<th>01/01/97-30/06/98 (18 months)</th>
<th>01/01/99-31/05/99 (5 months)</th>
<th>Both periods: 23 months</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>0</td>
<td>27</td>
<td>27</td>
<td>16.77%</td>
</tr>
<tr>
<td>Head/rear end</td>
<td>27</td>
<td>13</td>
<td>40</td>
<td>24.84%</td>
</tr>
<tr>
<td>Accident with pedestrian</td>
<td>32</td>
<td>7</td>
<td>39</td>
<td>24.22%</td>
</tr>
<tr>
<td>Head on</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>4.35%</td>
</tr>
<tr>
<td>Approach at angle</td>
<td>0</td>
<td>6</td>
<td>6</td>
<td>3.73%</td>
</tr>
<tr>
<td>Accident with fixed object</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1.24%</td>
</tr>
<tr>
<td>Accident with parked vehicle</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0.62%</td>
</tr>
<tr>
<td>Sideswipe - same direction</td>
<td>18</td>
<td>1</td>
<td>19</td>
<td>11.80%</td>
</tr>
<tr>
<td>Single vehicle overturned</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>2.48%</td>
</tr>
<tr>
<td>Sideswipe - opposite direction</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1.86%</td>
</tr>
<tr>
<td>Turn in face of traffic</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>3.11%</td>
</tr>
<tr>
<td>Right angle collision</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0.62%</td>
</tr>
<tr>
<td>One or both turning</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>1.86%</td>
</tr>
<tr>
<td>Reversing</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>2.48%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>97</td>
<td>64</td>
<td>161</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

### TABLE 4: LOCATION OF ACCIDENTS (PERIOD FROM 1/6/98 TO 31/5/99)

<table>
<thead>
<tr>
<th>Street intersecting with Maunde Street</th>
<th>Fatal</th>
<th>Serious Injury</th>
<th>Injury</th>
<th>Damage only</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makaza</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mphalane</td>
<td></td>
<td>2</td>
<td>5</td>
<td>23.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sekhu</td>
<td></td>
<td></td>
<td>3</td>
<td>10.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nchare</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tau</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tlou</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mhlanga</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hlahla</td>
<td></td>
<td>5</td>
<td>5</td>
<td>16.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magombane</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senthumule</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mokgatle</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Khudu</td>
<td></td>
<td>1</td>
<td>1</td>
<td>3.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moloantoa</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>6.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>23</td>
<td>30</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
TABLE 5: GRADE OF ACCIDENTS

<table>
<thead>
<tr>
<th>Period for which data is available</th>
<th>Fatal</th>
<th>Serious Injury</th>
<th>Injury</th>
<th>Damage only</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/97 - 30/6/98 (18 months)</td>
<td>3</td>
<td>17</td>
<td>14</td>
<td>63</td>
<td>97</td>
</tr>
<tr>
<td>1/7/98 - 31/5/99 (11 months)</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>25</td>
<td>19</td>
<td>132</td>
<td>180</td>
</tr>
<tr>
<td>Percentage</td>
<td>2.2%</td>
<td>13.9%</td>
<td>10.6%</td>
<td>73.3%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

TABLE 6: TIME OF DAY WHEN ACCIDENTS OCCUR

<table>
<thead>
<tr>
<th>TIME PERIOD</th>
<th>1/1/97-30/6/98</th>
<th>1/7/98 - 31/5/99</th>
<th>Total</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>06:00 - 09:00</td>
<td>6</td>
<td>20</td>
<td>26</td>
<td>15.6%</td>
</tr>
<tr>
<td>09:00 - 16:00</td>
<td>35</td>
<td>26</td>
<td>61</td>
<td>36.5%</td>
</tr>
<tr>
<td>16:00 - 18:00</td>
<td>8</td>
<td>14</td>
<td>22</td>
<td>13.2%</td>
</tr>
<tr>
<td>18:00 - 06:00</td>
<td>35</td>
<td>23</td>
<td>58</td>
<td>34.7%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>84</td>
<td>83</td>
<td>167</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

TABLE 7: LOCATION OF ACCIDENTS WITH PEDESTRIANS (1/1/97-30/6/98)

<table>
<thead>
<tr>
<th>Location of accident with Pedestrian</th>
<th>Total for period</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing street at intersection</td>
<td>7</td>
<td>28.0%</td>
</tr>
<tr>
<td>Crossing street between intersections</td>
<td>12</td>
<td>48.0%</td>
</tr>
<tr>
<td>Walking in the street</td>
<td>6</td>
<td>24.0%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>25</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

2.6 Problems identified by the community and ASTRASA

The following problems were identified by the community:

- Elderly and children are walking from the informal settlement in the west to the station, crossing Maunde Street west of Makaza Street.
- Speed humps are required for the western section of Maunde Street.
- The implementation of traffic circles is a problem, motorists do not know who has right-of-way.
- Pedestrian walkways on both sides of Maunde Street would improve safety. At present there is only a walkway on the northern side.
- Signage on Maunde Street to major attractions and community facilities.
- The 3-way stop control at the intersection of Moloantoa- and Maunde Streets is ignored, speed humps are required.
The taxis moved from Maunde Street to Ramokgopa Street, because of the speed humps in Maunde Street.

More speed humps are required between Mphalane- and Sekhu Streets.

Speed humps are required at the intersections of Maunde Street with Nchare- and Ramano Streets, due to the schools on both sides of Maunde Street.

The taxis use the sidewalks to skip the intersections and stop streets.

### 2.7 General problems observed with field surveys

Table 8 shows the general problems observed with field surveys. This confirmed problems identified by the community.

<table>
<thead>
<tr>
<th>Nr</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stop control at intersections is ignored.</td>
</tr>
<tr>
<td>2.</td>
<td>Utilisation of the taxi and bus bays should be addressed.</td>
</tr>
<tr>
<td>3.</td>
<td>Street lighting should be improved.</td>
</tr>
<tr>
<td>4.</td>
<td>A traffic problem is experienced during funerals at the two cemeteries next to Maunde Street.</td>
</tr>
<tr>
<td>5.</td>
<td>The absence of paving behind the existing mountable kerb result in gravel and sand being washed into the road surface.</td>
</tr>
<tr>
<td>6.</td>
<td>The several Informal trade stalls result in pedestrians having to walk in the street to pass these hawker stands.</td>
</tr>
<tr>
<td>7.</td>
<td>The provision of rails or barriers to channelize people waiting for taxis on the sidewalks should be considered.</td>
</tr>
<tr>
<td>8.</td>
<td>Taxis pile-up in the intersections to make U-turns to pick up passengers in the intersection, before continuing on their routes.</td>
</tr>
</tbody>
</table>

### 3. Problem Identification and Analyses

#### 3.1 Traffic Control

The existing traffic control on Maunde Street is stop control - most streets intersecting with Maunde Street has stop control (on the intersecting street) and a few intersections has all-way stop control.

To determine the optimum type of control at an intersection, the aspects that need to be considered include traffic safety, capacity and level of service. The feasibility of providing traffic signals or other form of traffic control was specifically investigated at a few intersections, namely:

1. Mphalane / Maunde
2. Sekhu / Maunde
3. Hlahla / Maunde
The provision of traffic signals at these intersections are not supported, for the following reasons:
   · The traffic volumes on the side streets are lower than the minimum required in the South African Road Traffic Signs Manual.
   · The speed of vehicles through the intersections may increase - not the average speed, but the speed of individual vehicles as they speed to go through on either the end of green or through yellow.
   · It will be more effective to provide raised pedestrian crossings for school children as it will force motorists to reduce speed and yield for pedestrians. People don’t cross at the intersections.
   · In the South African Road Traffic Signs Manual (Volume 1, Part 3, Par 6.8.2.2) it is also clearly stated that collisions may increase at traffic signals, although the type and severity of collisions may change.
   · The provision of mini-circles was also investigated as a method of control at the intersections. Mini-circles however, do not always function well in conjunction with high pedestrian volumes.

The above motivation can be applied to the approval of traffic signals in other similar areas. The results of the capacity analyses also show that most intersections operate at acceptable levels of service at present.

3.2 Traffic Safety
A detailed analyses of accident statistics was done as part of the Status Quo investigation. The main causes of accidents, can be summarised as follows:

   · Poor driver behaviour - this includes speeding, ignoring stop control at intersections and taxis loading passengers anywhere and not only at the designated bays.
   · Poor pedestrian behaviour - this includes ”jay walking”, not waiting for taxis at the designated loading bays, walking in the roadway.
   · The above two issues relate to education of drivers and pedestrians as well as to law enforcement.
   · The impact of vehicles that are not roadworthy on traffic safety is not quantified in this report but should be addressed through law enforcement.

The following physical aspects of Maunde Street were identified as problems which need to be addressed:

   · Lighting - the high frequency of accidents at night show clearly that the lighting is inadequate.
   · Pedestrian / vehicle conflict can be controlled through reducing speed by the provision of additional raised pedestrian crossings - at intersections and midblock.
   · Vehicles stopping on the side walk at locations other than the designated taxi bays can be controlled by erecting vertical kerbs and painting a red no stop line. The red line will assist in law enforcement.
   · The fact that a paved sidewalk or pedestrian path is only provided on the one side
of Maunde Street (the northern side) for the largest length thereof, possibly result in pedestrians crossing the street between intersections to walk on the sidewalk. There is a need for a pedestrian walkway both sides of the road.

- Apart from the fact that the existing sidewalk is not aesthetical, the unpaved area force pedestrians onto the road when it rains to avoid standing or walking in the mud.
- A significant problem is hawkers that have shelters within the road reserve, especially where their stands extend over the pedestrian walkway.

To address the above mentioned problems and to improve traffic safety, a range of physical measures can be implemented. The different measures are shown in Table 9.

**Table 9: Possible Physical Measures to Improve Road Safety**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Measure</th>
<th>Application and function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Provision of a median island</td>
<td>Reduce turning movements, refuge for pedestrians</td>
</tr>
<tr>
<td>2</td>
<td>Limit turning and conflict movements</td>
<td>Improve traffic safety</td>
</tr>
<tr>
<td>3</td>
<td>Speed humps</td>
<td>Reduce speed</td>
</tr>
<tr>
<td>4</td>
<td>Pedestrian Paths</td>
<td>Separate pedestrians and vehicular traffic</td>
</tr>
<tr>
<td>5</td>
<td>Additional turning lanes</td>
<td>Improve capacity and reduce vehicle conflict</td>
</tr>
<tr>
<td>6</td>
<td>Provide vertical kerbing</td>
<td>Protect pedestrians on side walks</td>
</tr>
<tr>
<td>7</td>
<td>Provide raised pedestrian crossings</td>
<td>Reduce speed and improve pedestrian safety</td>
</tr>
<tr>
<td>8</td>
<td>Improve lighting</td>
<td>Improve traffic safety at night (sight distance)</td>
</tr>
<tr>
<td>9</td>
<td>Provide additional signage</td>
<td>Warning signs to improve driver awareness</td>
</tr>
<tr>
<td>10</td>
<td>Reduce number of direct erf accesses</td>
<td>Reduce conflict movements</td>
</tr>
<tr>
<td>11</td>
<td>Reduce traffic volumes by diverting traffic to other roads</td>
<td>Improve spare capacity, reduce through traffic and hence conflict movements</td>
</tr>
<tr>
<td>12</td>
<td>Channelize pedestrians</td>
<td>Improve pedestrian safety</td>
</tr>
<tr>
<td>13</td>
<td>Remove or control hawkers from side walks</td>
<td>Improve pedestrian level of service</td>
</tr>
<tr>
<td>14</td>
<td>Change control of intersections to circle control or traffic signals</td>
<td>Improve capacity, not necessarily traffic safety</td>
</tr>
<tr>
<td>15</td>
<td>Additional bus and taxi bays</td>
<td>Improve public transport level of service</td>
</tr>
<tr>
<td>16</td>
<td>Provide shelters for bus and taxi bays</td>
<td>Improve public transport level of service</td>
</tr>
</tbody>
</table>
14. PROPOSED ROAD UPGRADES TO IMPROVE TRAFFIC CONTROL AND ROAD SAFETY

The different measures identified in Section 3.2 were applied for the whole section of Maunde Street. The total cost of the proposed measures, as proposed in Table 10, is approximately R 1.5 million. A prioritisation of the measures is proposed to assist in planning for the implementation thereof. Some of these measures are under construction at present.

**TABLE 10: PRIORITISATION OF MEASURES AND ESTIMATED COST**

<table>
<thead>
<tr>
<th>Priority</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 Additional raised pedestrian crossings</td>
<td>R70,000</td>
</tr>
<tr>
<td>2</td>
<td>Pedestrian walkways south of Maunde Street</td>
<td>R299,000</td>
</tr>
<tr>
<td>3</td>
<td>Improvement of road markings</td>
<td>R39,500</td>
</tr>
<tr>
<td>4</td>
<td>Improvement of street lighting</td>
<td>R75,000</td>
</tr>
<tr>
<td>5</td>
<td>Provision of vertical kerb at intersections</td>
<td>R70,000</td>
</tr>
<tr>
<td>6</td>
<td>Additional turning lanes at Hlahla and Maunde Street</td>
<td>R160,000</td>
</tr>
<tr>
<td>7</td>
<td>Provision of paving around intersections</td>
<td>R488,400</td>
</tr>
<tr>
<td>8</td>
<td>Provision of additional taxi bays</td>
<td>R84,000</td>
</tr>
<tr>
<td>9</td>
<td>Provision of paving behind taxi bays</td>
<td>R224,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>R1,509,900</strong></td>
</tr>
</tbody>
</table>

Figure 2 show a typical plan of some of the measures that are implemented.

5. ADDITIONAL ACTIONS UNDERTAKEN BY THE CITY COUNCIL, ASTRASA AND GAUTRANS

The following actions were also undertaken in addition to the road improvements below. These actions have reference to the specific problems as identified in the report.

5.1 Education

Gautrans Road Safety Promotion will provide road safety education to the residents living along Maunde Street. Educational material such as leaflets and audio visual media will be used at schools, clinics and along the street. The local road safety forum ASTRASA (Atteridgeville / Saulsville Road Safety Forum) will be linked into the project through information sessions on community meetings, workshops and general assistance with Gautrans Road Safety Promotion.
5.2 Marketing

ASTRASA, together with City Council of Pretoria and Gautrans, is involved with the launch of the project before and after completion. The relevant local print media will be invited as well as all relevant role-players and stakeholders. An information billboard was erected.

5.3 Law Enforcement

In addition to the involvement of the local Pretoria Law Enforcement team, the Gautrans Pretoria Regional Office was also brought in to provide a supplementary service. The two teams will work in co-operation with one another and will assist in joint law enforcement campaign after the completion of the project. The local SAPS will also be drawn in to provide a backup service.

Speed measurement, visible patrolling, road blocks (K78) and selective law enforcement will be the main thrust of the law enforcement agencies on Maunde Street.

6. FINDINGS

The Maunde Street Traffic Safety Project had a specific focus, namely to improve safety in a higher order street through a Township Street. The findings from the study are generalised to assist in the execution of other similar projects in future:

- Township Streets have unique problems. Maunde Street is an example of many typical streets in Townships - a relative high mobility function combined with direct residential access, public transport usage and high pedestrian volumes.

- The verges on these roads are seldom paved or grassed which result in pedestrians within the roadway, gravel on the road reducing skid resistance and an overall poor aesthetical appearance.

- The vehicle volumes on these roads are seldom high enough to warrant traffic signals, although there can be pressure in many cases from the community to provide traffic signals. The disadvantages of traffic signals in terms of safety should be clearly explained to the community and should only be implemented where the traffic demand adequately warrants it.

- This study showed that a proper engineering analyses, based on adequate traffic data - volumes, accident statistics etc, combined with community participation, can deliver traffic safety solutions that can be expected to yield results.

- There are a limited range of physical measures that can be done from an engineering perspective to improve traffic safety. These typical measures are listed in Table 9. The implementation of such measures should coincide with a proper education and law enforcement programme.
Figure 2: Typical upgrades at intersection

Figure 1: Study Area
30 km/h in urban areas

Christer Hydén, Lars Ekman

Abstract

As a result of the Swedish “Vision Zero” the interest for speed management has increased. 30 km/h zones is considered an important “tool” to achieve the goal. The aim of our project is to assess some new 30 km/h zones and to develop planning methods to support traffic planners. Within the project we have developed two new methods, “Area wide speed measurements” and “Automated video based studies of pedestrian crossing behaviour”. Our results show that speeds in residential areas often already are low and that the counter-measures used do not fulfil the “Vision Zero” goal, since the 85 percentile often is above 30 km/h. We have encountered behavioural modifications both on pedestrians and drivers. The behavioural modifications could be interpreted both positively and negatively from a safety point of view. Car drivers seem to be more willing to yield for pedestrians at pedestrian crossings when the speed is reduced. Often are safety projects evaluated in terms of intentions or action taken rather than the effect on traffic behaviour. One of the conclusions from the project is that operational and concrete evaluation is needed if the “Vision Zero” shall be fulfilled with reasonable resources.

The results of the project mentioned above will be complemented with a discussion about a holistic approach to speeds and safety on the whole road network in cities. This part will include possible strategies on arterial roads and also results from some projects dealing with the effects of speed strategies on arterials.

Finally the paper will include a discussion of the possible implications of results and experiences reached in Sweden for the development of strategies in developing countries. To what extent - and on what level - are problems identified in Sweden relevant for developing countries, and to what extent are measures and strategies applicable under the different conditions in developing countries.
Session 9    Designing and Operating Work Zones for Increased Safety

4-0 and 3-1 contraflow workzone areas: Effects on driving behaviour, workload and comfort  
*Marieke Martens*

New regulation for designing and operating work zones in the Czech Republic, theory and the first practical experiences  
*Pavel Tucka*

Distribution and characteristics of crashes at different locations within work zones in Virginia  
*Nicholas J. Garber*

Incident Management Programs in the United States  
*Richard A. Cunard*
4-0 and 3-1 contraflow workzone areas: Effects on driving behaviour, workload and comfort.

Marieke H. Martens, Karel A. Brookhuis¹ & Alex P.P.M. van Loon²

TNO Human Factors, the Netherlands
¹Centre for Environmental and Traffic Psychology, the Netherlands

Abstract
In contraflow workzone areas, traffic of one carriageway is guided to the other carriageway with decreased lane width, either partially (3-1 type workzone) or completely (4-0 type workzone). According to the Dutch guidelines for workzone areas, a contraflow system is only allowed to have a maximum length of 4 km, since otherwise it is supposed that road users experience too high a workload. The present study investigated the effects of long contraflow systems (up to 12 km) on lateral position, longitudinal control, speed, road marking crossings, steering performance, workload and subjective evaluation. The study included a driving simulator study, video observations of traffic behaviour at contraflow systems, and a study with an instrumented vehicle at prolonged contraflow-systems.

The driving simulator study investigated the effect of type of contraflow system, lane width and length of the contraflow system on driving behaviour, workload and subjective safety. Video images of traffic behaviour at transitions from a standard motorway to both contraflow systems were analysed and effects of both contraflow systems on real driving behaviour and physiological measures were studied by means of driving in an instrumented vehicle in actual traffic.

The three separate studies showed to be complementary. The driving simulator study (with simulated cars and heavy vehicles surrounding the subject) showed a clear difference in driving behaviour and subjective safety between 3-1 and 4-0 type workzones. Lane width also turned out to affect driving performance. The study with the instrumented vehicle showed effects on driving behaviour and physical workload, with the effect of length being in correspondence with the results found in the driving simulator study. The video images showed high turbulence in the traffic flow in front of the workzones due to a fairly high amount of lane changes. This may be explained by drivers trying to avoid the traffic lane where heavy traffic is allowed.

Based on the results of the three studies together, safety recommendations were proposed for designing safe contraflow systems, with attention paid to lane width, type of workzone system and length of the workzone.

1 Introduction

In contraflow workzone areas on motorways, traffic from one carriageway is guided to the other carriageway with decreased lane width. Road users can be guided to the other carriageway either partially with one lane on the other carriageway (3-1 type workzone) or completely with 2 lanes to the other carriageway (4-0 type workzone). According to the Dutch guidelines for workzone areas, a contraflow system is only allowed to have
a maximum length of 4 km, since otherwise it is supposed that road users experience too high a workload.

Under contract by the Transport Research Centre (AVV) of the Dutch Directorate General of Transport, Public Works and Water Management, TNO Human Factors investigated the effect of long contraflow workzones on driving performance, workload and comfort, together with the Centre for Environmental and Traffic Psychology of the University of Groningen. The study concentrated on the question whether a contraflow system with a length of more than the usual 4 km would be acceptable in terms of driving behaviour, driving comfort and workload. For this, a distinction was made between a 3-1 and a 4-0 contraflow workzone. Also two types of lane width were investigated within each of the 2 workzones. Special attention was paid to the driving behaviour close to the transitions of a normal motorway lay-out to a contraflow workzone. To answer this question completely, the study consisted of three parts, a driving simulator study, video observations of the transitions and a study with an instrumented vehicle.

2 Driving simulator study

The driving simulator offered the possibility to properly investigate the effect of long contraflow zones, since long workzones up to 12 km are not yet actually in use. The driving simulator study investigated the effect of length of the contraflow system, type of contraflow system, and lane width on driving behaviour, workload and subjective safety.

In the TNO Human Factors driving simulator (for a detailed description see Hogema & Hoekstra, 1998; Hoekstra, van der Horst & Kaptein, 1997), a 3-1 and a 4-0 contraflow workzone were simulated conform the Dutch Guidelines for Workzones (CROW, 1995), with each two lane widths and a speed limit of 70 km/h. For the 3-1 workzone, the lane was either 2.50m or 2.75m wide. For the 4-0 workzone, the left lane was either 2.50m or 2.75m wide and the right lane was 3.00m or 3.25m wide. Subjects always drove on the left lane of the 4-0 system.

Altogether, 24 subjects participated and drove all 4 contraflow workzones, as well as a control condition in which they drove on a normal 2x2 lane motorway.

2.1 Task
Every subject started by driving the control condition, driving on a standard motorway. The control condition allowed a comparison between driving behaviour in contraflow workzones and normal driving behaviour. After this, each subject drove two 3-1 workzones (with 2 lane widths) and two 4-0 workzones (2 lane widths). The order in which subjects had to drive these workzones was balanced.

Subjects were free to choose their own speed. After each ride, subjects took a short break and were asked to fill in a questionnaire.

2.2 Dependent variables
Driving behaviour was measured by means of speed, standard deviation of lateral position, and steering behaviour, in terms of the proportion of high frequency steering (HFS). The proportion of HFS was calculated by dividing the energy in the 0.3-0.6 Hz area by the energy in the 0-0.6 Hz area (Blaauw, 1984). An increasing proportion of high frequent steering is an indication for difficult or strenuous steering. Also, Time-to-Line-
Crossing was calculated, which is a measure that indicates how close a driver is (in s) to crossing a road marking, as well as the percentage of actual road marking crossings (on the left side as well as on the right side).

2.3 Results

Speed
There was an effect of type of road condition on speed \[F(4,92) = 222.97, p<0.0001\], with higher speeds in the control condition. Also a main effect was found of type of contraflow workzone on driving speed \[F(1,23) = 4.59, p<0.043\], with lower speeds in the 3-1 workzone. A main effect of lane width was found \[F(1,23) = 9.93, p<0.004\], with higher speeds for wider lanes. A main effect was also present for distance within the workzone \[(F(2,46)=9.947, p<0.000)\], with higher speeds further in the workzone (for this, the 12 km workzone was subdivided in 3 parts). Since this latter effect was also found in the control condition, this is most probably caused by subjects getting used to the condition, instead of the workzone itself. Average driving speed was between 70 and 80 km/h.

Standard deviation of the lateral position
There was an effect of type of road condition on standard deviation of the lateral position \[F(4,92) = 67.91, p<0.0001\], with higher standard deviation of lateral position in the control condition. Neither a main effect of type of contraflow workzone nor a main effect of lane width was found on the standard deviation of lateral position. However, there was an effect of distance within the workzone \[F(2,46) = 21.83, p<0.000\], with higher standard deviation of the lateral position when subjects drove further in the workzone.

Proportion of HFS
There was an effect of type of road condition on proportion of HFS \[F(4,92) = 33.48, p<0.0001\], with a lower proportion of high frequency steering in the control condition. There was no main effect of type of contraflow workzone on the proportion of high frequency steering. Also no main effect was present of lane width. There was a main effect of distance within the workzone \[F(2,46) = 5.55, p<0.007\]. An interaction between type of contraflow workzone and lane width \[F(1,23) = 4.47, p<0.045\], with a decrease of HFS in the wide 3-1 workzone and an increase in the 4-0 system. An interaction was also present between lane width and distance within the workzone \[F(2,46) = 4.40, p<0.018\]. In the control condition, there was also a main effect of road section \[F(1,23) = 20.675, p<0.000\] with a lower decrease in HFS near the end of the road. The HFS was higher for the experimental conditions than for the control condition.
Figure 1: HFS in the different road conditions (contraflow workzones and the control condition) for the 3 subsequent road sections.

**Percentage road marking crossings**
The crossing of the left road marking was defined as subjects crossing the right side of the left road marking with the left side of the car. The percentages indicate how much of the time subjects were driving over this road marking. A main effect was present of type of workzone \( [F(1,23) = 31.50, p<0.000] \), with a higher percentage of left road markings crossing for the 4-0 workzone. There is also an effect of lane width \( [F(1,23) = 262.591, p<0.000] \), with less road marking crossings with wider lanes. Also, there is an effect of road section \( [F(2,46) = 16.437, p<0.000] \), with a lower percentage of left road marking crossings in the middle of the workzone.

In the control condition, there was no effect of road section, meaning that subjects did not cross the left road markings more or less, further on in the road section. Overall, the percentage left road marking crossings is high for the narrow lanes. Subjects drove very much towards the left hand side, probably trying to avoid any conflicts on the right hand side, since it is more difficult to judge how close one is to other traffic or the barrier on the right side. Figure 2 shows the percentage of crossings of left road markings.
Figure 2: Percentage of crossings of the left marking for the experimental conditions and the control condition for the 3 subsequent road sections.

No significant effects were found for crossing the right road marking.

Mean Time-to-Line-Crossing left road marking
Time-to-Line-Crossing (TLC) indicates the time until a driver will cross a road marking if he/she will keep the same course, the same speed and the same acceleration (or deceleration). A TLC value of 0 indicates that a driver starts to cross a road marking. Results show a main effect of contraflow workzone on TLC_{left} [F(1,23) = 22.04, p<0.001], with higher values for the 3-1 workzone. Also lane width has a main effect [F(1,23) = 131.86, p<0.001], with higher values for the wider lanes. A main effect was found of section [F(2,46) = 7.11, p<0.002], with higher TLCs for the middle section. Figure 3 shows the mean TLC_{left}-values for the different conditions.

Figure 3: Effect of condition on mean TLC_{left} in the control conditions and the experimental condition for the 3 road sections.
For the TLCs on the right hand side, no significant effects were found.

**Questionnaires**

Subjects indicated that driving in contraflow workzones was more strenuous than driving on a normal motorway, with the 4-0 workzone leading to more strenuous driving than the 3-1 workzone. They stated that driving was not more difficult after a longer period of time inside the workzone. Even the wide lane in the 4-0 contraflow workzone was judged as narrow. Their overall preference was for the 3-1 workzone.

**2.4 Conclusions of the driving simulator study**

In summary, the results show that a long 3-1 contraflow workzone with a lane width of 2.50m is not to be recommended. Subjects' steering was more strenuous than in other workzones, while their standard deviation of the lateral position got larger. This indicates that in spite of steering with more effort, it is harder to keep a stable lateral position. The fact that this driving behaviour occurs in a narrow lane even enlarges the chances of incidents. In situations in which a 3-1 workzone with a lane of 2.50m is necessary, it is strongly recommended to limit this to a workzone with a length of 4 km. With a 2.75m wide driving lane, the standard deviation of the lateral position increases after 8 km. The effort subjects put into steering did not change over the length of the workzone. This results in the recommendation not to exceed the length of 8 km for a 3-1 contraflow workzone with a lane of 2.75 m.

For the 4-0 workzone with a left lane width of 2.50m, the standard deviation of the lateral position increased further on in the workzone, even though people show more strenuous steering the longer they drive in the workzone. Similar to the narrow 3-1 workzone, this indicated that in spite of putting more effort into steering, it is harder to keep a stable position within the lane. For the lane width of 2.75m., there is also an increase in the standard deviation of lateral position after driving on this lane for a longer period of time, in combination with more strenuous steering behaviour. This, again, is an indication of higher chances of incidents. With this, there is an increase in the number of lane marking crossings on the right side after driving in the work zones for a longer period of time. 4-0 workzones with lengths over 4 km are therefore not recommended.

**3 Video registration of transitions**

The driving behaviour during driving through the transitions from a normal motorway to a 3-1 workzone and a 4-0 workzone was measures by means of video registration. The conflicts occurring were analysed. Trucks as well as normal traffic (cars) were included in the analysis. Per location, 6 hours of video were produced.

**3.1 The 3-1 contraflow workzone**

The lateral positioning of drivers in the left driving lane of the transitions of a normal motorway to a 3-1 workzone was analysed. On the left lane, no trucks were allowed. Yellow road markings were used to indicate the driving lane and red-white beacons were used on the left side, and a barrier is used on the right side.

Road users use all the space available to make the curve in the transition as large as possible. Thereby they cross the lane markings, as long as there is space available on the left side of the road marking. Since there is
a concrete barrier on the right side, drivers want to keep as far as possible from this. Because of this, road users enter the 3-1 workzone on the left side of the lane, and they correct their position after the transition.

A 3-1 workzone forces the driver to choose one particular driving lane (left or right, with the right lane being wider than the left lane). In order to do this in ample time, there is an uninterrupted road marking separating the left and right driving lane. The video registration showed that road users ignore this, and they still change lane very close to the lane separation, thereby crossing the uninterrupted road marking. In those cases, car drivers change more often from the right to the left lane instead of the other way around. This can be explained by the fact that they want to avoid trucks in front of their vehicles because of low speed and limited view. About 1% of all traffic changed from left to the right lane, crossing the uninterrupted road marking and up to 3% changed from the right to the left lane.

3.2 The 4-0 workzone

Also in the 4-0 workzone, an uninterrupted road marking is used to separate the left and right driving lane. The data on the left and the right driving lane were analysed separately. About 74% of all traffic (including trucks) in the right driving lane does not cross any road marking, and stays within their lane. Even though the majority stays within their lane, the majority also brakes before entering the curve in the transition, basically indicating they are driving too fast in front of the transition. About 24% of the road users touch the left road marking in the beginning of the transition. This is about 34% in case of trucks only. About 2% of all traffic changes to the left driving lane within the transition, but these are cars only.

The majority of the traffic in the left driving lane (88%) stays within their lane. About 8% of the road users touch the right road marking with their wheels. About 1% touches the left road marking. Since there is less space available to cross the road marking, this result was to be expected. About 3% changes from the left to the right driving lane during the transition.

Summarising, these results show that quite a lot of traffic still changes lane just before or even in the transition, even though this is not permitted. In the 4-0 system, changes from the left to the right lane are about equal in number to the changes from the right to the left lane. They are probably only used to make the curve less sharp. In the 3-1 workzone, more road users change from the right to the left lane. Independent of the type of workzone, road users use all available space to cut the corner. In order to avoid any conflicts, it is therefore advised to use a double interrupted line to emphasise its importance. In the 4-0 workzone, accurate lateral positioning is more important since there is traffic in the adjacent lane. Therefore the 3-1 system is to be preferred, especially in high traffic volume situations. The video registrations did not show any major conflicts.

4 Instrumented vehicle study

To gain insight in the effects of contraflow workzones on appraisal, workload and driving behaviour in actual traffic, a small field experiment was carried out in an instrumented vehicle. This part of the study is typically a supplement to the simulator study in the sense that it concerns measurements of actual driving behaviour on a real motorway. The results are however limited in the sense that it is confined to contraflow workzones as coincidentally offered in the period of the project. In practice the contraflow workzone consisted of a 3-1 workzone with lanes of 2.50m (left lane) and 3.00m (right lane) including 15cm yellow road marking and a
4-0 workzone with similar lane widths. The maximum length of the workzone, the 3-1 type, was 7 kilometres.

4.1 Subjects
In total 29 subjects voluntarily participated (16 male, 13 female), of which 16 drove the 3-1 workzone and only 13 drove the 4-0 workzone. Subjects were recruited via local newspapers in the neighbourhood of the workplace. Mean age was 42 years (range 23 – 63), possessing a driving license on average for 21 years (range 5 – 36), driving experience more than 22,000 km/year (range 5,000 – 130,000).

4.2 Task
All subjects were hosted in a local hotelroom, where they received instructions, completed some general questionnaires, and got heart rate electrodes fixed to enable measurement of mental workload (De Waard, 1996, Brookhuis & De Waard, 2000). All subjects drove the complete test track twice, once during rush hours and once in quiet hours. The test track consisted of a normal, control part and the contraflow workzone. After each part of the test track, specific questionnaires were completed concerning appraisal and subjective mental workload. For safety reasons dual controls were present and the subjects were instructed to drive as they would normally do, leaving choice of speed and traffic lane free.

4.3 Dependent variables
The behavioural consequence of driving within a contraflow workzone is operationalised in terms of both longitudinal and lateral position changes. Average and variance (standard deviation) of speed and lateral position were calculated across control and workzone tracks. Naturally, the traffic lanes differed between different conditions, reason why a relative lateral position was calculated:

\[
\text{relative lateral position} = \frac{\text{absolute lateral position}}{\text{lane width}} \times 100\%
\]

Changes in discomfort and mental workload were measured in two ways, by objective measures derived from heart rate and subjective measures (BSMI) (see Brookhuis, 1993; De Waard, 1996; Zijlstra & Meijman, 1989).

4.4 Results

Lateral position
No difference was found in lateral position data between rush hours and normal hours. The impression was, however, that traffic density did not differ very much between hours of daytime at the time of experimentation. Relative lateral position on the longest track, the 3-1 contraflow workzone, was significantly more to the right in the narrow workzones than on the control tracks \(F(1,13) = 80.1, p<0.001\). The standard deviation in lateral position was significantly lower on the narrow lanes than on the normal control lanes \(F(1,13) = 13.1, p<0.004\).

Figure 4 shows the effects on relative lateral position on all double-lane tracks.
Figure 4: Mean relative lateral position on left- and right traffic lane in control- and workzone conditions.

**Speed**

For the speed also no difference was found between rush hours and normal hours. Naturally, speed was much lower on the workzone traffic lanes ($F(1,13) = 589.9, p<0.001$) and $F(1,5) = 749.1, p<0.001$ respectively the 3-1 and the 4-0 system). In the control lanes mean speed was 120 km/h, while in the actual workzones mean speed was 80 km/h, whereas at the point of passing the sign indicating that the speed limit is 70 km/h, the actual speed was still between 90 and 100 km/h. No differences between traffic lanes were found.

**Heart rate**

Again no difference was found between rush hours and normal hours. In the approach of the workzones, clearly and far in advance indicated, heart rate increased considerably, after some time decreasing to a level that was even lower than in the control conditions ($F(1,13) = 12.9, p<0.003$ and $F(1,5) = 14.5, p<0.002$ respectively), see figure 5. The anticipatory effects at around the 70 km/h sign (Dutch: “bord 70”) are clearly visible too.
Subjective workload and appraisal
Driving in the contraflow workzones was judged significantly more effortful than in the control tracks in all cases \[F(1,27) = 47.0, \ p<0.001\], no differences were found between rush hours and normal hours.
Both the 3-1 and the 4-0 system were judged by subjects as useful, with a slight preference for the 3-1 system \((F(1,27) = 4.9, \ p<0.039)\). Subjects rated the comfort on workzones neutral, , which allows the conclusion that the systems arouse no irritation.

4.5 Conclusions instrumented vehicle study

As expected, there were large differences between driving on the control parts of the test track and in the contraflow workzones. Subjects drove much slower (although still too fast in the workzones), more to the right and with less weaving. They judged this type of road works useful (3-1 more so than 4-0) and not uncomfortable, indicated to exert more effort but were not under higher mental pressure, probably due to the lower speed which lowers strain. An advice was given to position an extra speed limit sign (90 km/h) at ample distance before the 70 km/h speed limit sign.

The following general conclusions can be drawn up:
1. Drivers adapt to the contraflow system
2. They do so by driving more carefully
3. This brings no unacceptable strain
4. A 3-1 contraflow system of 7-kilometre length is not strenuous in this sense
5. The differences found in this study between a 3-1 system and a 4-0 system do not give rise to strong preferences.
NEW REGULATION FOR DESIGNING AND OPERATING

WORK ZONES IN THE CZECH REPUBLIC

THEORY AND THE FIRST PRACTICAL EXPERIENCES

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1. INTRODUCTION

The long-term development of the accident rate has shown the vehement increase of accident and their consequences after 1987 in the Czech Republic. The accident increase especially within last six years has been enormous. As is shown on Fig. 1, number of accidents expanded more than three times, number of seriously injured is over 73 percent higher. The estimation of total losses for society (according methodology of CDV) e.g. per 1993 was 537.9 million ECU (referring to GDP - Gross Domestics Product - it means 1.8%) and per 1998 it was already 1026 million EURO (referring to GDP it means 2.2%).
The development of road safety also reflects very clearly all economical, social and political changes in our society in the Czech Republic. These changes lead to the changes in the social atmosphere and in the changes of road users behaviour. This factor is based on the feeling on the achieved freedom and it is resulting in the lower legal responsibility of road users. It is also connected with bad position of police enforcement. In result of these relations it comes to vigorous pressure to better orientation in traffic flow and its controlling and to executing to the traffic measures in quantitative higher level.

The problems of work zone designing and ensuring were substantially underestimated for twenty years period and so far there existed only one technical publication dealing with the problems, which did not in addition include (and not even to this scope could include) the entire extensity of the problems for all this period.

2. CONTENT OF THE REGULATION „THE PRINCIPLES FOR TEMPORARY TRAFFIC SIGNING ON ROADS"

On the base of depth analyse of analogous regulations and guidelines of European countries and using the Czech Highway Code as well as appropriate technical standards and regulations was elaborated the first version of new Czech regulation in the end of 1994. This regulation was examined in practice and in the end 1996 was issued final version. The regulation is drawn up as the practical handbook with safety principles and a lot of examples of traffic system plans for rural roads, urban roads and motorways, too.
The biggest pressure on ensuring work zones was primary on motorways. This need also issues from the fact, that rate-off accidents on motorway work zones is about 56% of all accidents on work zones of the rest roads, and at the same time length our motorways is only 0,37 percent from length of whole road network. Level of ensuring of motorway work zones must be obviously the highest.

The Figure No. 2 shows an example of one of selected traffic system plan with long term duration for motorways. It is concerned the event of works in the median with two auxiliary traffic lanes along. The whole work zone area was divided into these parts:

- **Advance warning area**

  The traffic signs, possibly traffic devices installed in this area warn and prepare the drivers to new following driving situation. In this area it is primarily necessary to reduce vehicle’s speed and sufficiently inform drivers about the direction changes and other certain changes which will immediately come after in next work zone area - narrowing area.

- **Narrowing area**

  In this area there is the traffic line diverted and the line width is reduced. These measures are realised by using transverse closure composed from guiding beacons fulfilled with warning traffic lights (on left site with high intensity, on right side with lower intensity). The auxiliary traffic lanes are delimited by road studs or by foil for better driver guidance in this area.

- **Work area**

  In this area the traffic is running along the construction place. It is important to keep sufficient safe distance between traffic line and the working area where are the workers moving. This measure can be for instance realised by placing longitudinal closure. The closure consists of guiding beacons and every second beacon is supplemented by warning light with lower luminous intensity and road studs.

- **Termination area**

  The traffic lines are diverted back to the previous direction and width in this area. The diversion is again realised by using transverse closure without warning lights and traffic lines are determined by road studs.

- **Run-off area**

  All restrictions are off and normal traffic conditions are resumed.
Figure 2

2 auxiliary traffic lanes in case of works in the median and existing shoulder

Transverse closure by guiding beacons
Angle of standing approx. 1 : 10
Spacing max. 10 m

Longitudinal closure by guiding beacons
Spacing max. 20 m

Transverse closure by guiding beacons
Angle of standing approx. 1 : 20
Spacing max. 10 m
Type 1 warning lights on the left closure on every guiding beacon

Marking of traffic lanes with road studs (spaced at 0.3 - 1 m) or with foil

1) Repeated every 1000 m in case of works sites longer than 1000 m

Type 1 warning light

All distances in metres
General safety principles for work zone applied to traffic system plans:

- visibility of work zone (WZ) for road users,
- uniformity of WZ form,
- optimal sequence of measures (traffic signs and devices) on WZ,
- comprehensibility of WZ for road users.

Safety principles for the design of work zone:

- the work zone traffic signing should be provided by the same way in similar situations,
- traffic guidance in work zone area has to unambiguously, clearly and easily cognizable for road users. All traffic signs and devices have to be easy visible and understood,
- to lay stress on driver’s directional guidance through the work zone (by means of guiding equipment, road studs, sheeting, suitable and uniform angle of standing of transverse closures, ...),
- to establish buffer zone especially in the case of work zone on roads with more than three lanes,
- in the case of requirement to close lane on motorway or dual carriage way, it is necessary to close lane(s) from the left side „quick lane(s)” and conduct traffic through the right line(s),
- it is important to look at the ensuring of cyclists, pedestrians and workers, too (e.g. its division from traffic),
- traffic signs and traffic devices should be used (valid) only for necessary long term (only during works on road, if it is possible),
- used traffic sign and traffic devices have to be updated according to the stage of works in work zone.
3. ACCIDENT DEVELOPMENT IN THE WORK ZONES IN THE CZECH REPUBLIC

The development of road accidents in the work zones is shown on Figure 3. The development of number of accidents in the work zones follows the increase of accident on all roads. Since 1997 the new regulation has been valid and used in practice. After 1997 we can see decreasing tendency of number of slightly and seriously injured persons. The decrease of number of slightly and seriously injured persons in the work zones is more distinct than the one on all roads.

![Accident development in the work zones](image)

Figure 3

The effectiveness of the proposed measures in work zones can be also demonstrated by the analysis of selected types of work zone accidents. For example since 1997 we have recorded every year about 20% decrease of accident numbers in the work zones caused by inappropriate driver’s speed. On motorways these numbers are constant. Since 1997 we have not recorded any traffic accident caused by entering to the opposite direction.
4. CONCLUSION

If we take into account this unsafe situation on our roads we can state, that during a short time period (about three years of experiences) and statistically small numbers, we succeeded the decrease of number of slightly and seriously injured in our work zones areas.

I hope that consistent application of the safety principles described the new regulations helps to improve current state in these areas and it can contribute to solve the problem of traffic unsafety in the frame work of the „System program of road safety increasing“.

As next step we plan to test the usage fluorescent retroreflective sheeting on traffic signs because of increasing of number accidents and rear-end collisions especially in advanced warning area of the work zone. The idea is to build up something as a work zone gate with the aim to increase driver’s attention. Actual research shows quite significant increase of drivers attention in case of application of fluorescent retroreflective material on sheeting especially on rural areas.
DISTRIBUTION AND CHARACTERISTICS OF CRASHES AT DIFFERENT LOCATIONS WITHIN WORK ZONES IN VIRGINIA

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ABSTRACT

Work zones tend to cause hazardous conditions for vehicle drivers and construction workers since these work zones generate conflicts between construction activities and the traffic, and therefore aggravate the existing traffic conditions. Every effort should therefore be made to minimize the negative impacts of work zones. A clear understanding of the characteristics of work zone crashes will enhance the selection of the appropriate measures that can minimize the negative impacts of work zones.

This study investigated the characteristics of work zone crashes in Virginia that occurred between 1996 and 1999. The information on each crash was obtained from the police crash records. Each crash was located in one of five areas of the work zone; (i) Advance Warning Area, (ii) Transition Area, (iii) Longitudinal buffer Area, (iv) Activity Area, and (v) Termination Area. An analysis of the percentage distributions was then carried out, with respect to the locations of the crashes, the severity, collision types and different types of highways. The proportionality test was used to determine significant differences at the 5% significance level. The results indicate that the Activity Area (Area 4) is the predominant location for work zone crashes regardless of the highway type, and that rear-end crashes are the predominant type of crashes. However, the results also indicated that the proportion of the sideswipe in same direction (SS) crashes in the Transition Area (area 2) is significantly higher than that in the Advance Warning Area (Area 1).
INTRODUCTION

With the completion of the interstate highway system in the United States, the roadwork has shifted from new construction to maintenance and rehabilitation. The transportation Equity Act for the 21st Century (TEA 21) provided a significant increase in the funding for highway construction and maintenance. Thus, it is expected that rehabilitation work will increase significantly during the next few years. In addition, it is expected that traffic volumes on the Nations’ highways will continue to increase. Since it is not feasible to close long stretches of highways while rehabilitation work is being undertaken, it will be necessary to provide for the flow of the increased volumes of traffic while rehabilitation work is in progress. This in turn will result in a significant increase in the number of work zones, which will require an increased effort in improving safety at work zones. However, a clear understanding of the characteristics of work zone crashes will enhance the selection of effective counter measures that can be used to minimize the negative effects of work zones. This study is a thorough examination of the characteristics of work zone crashes in Virginia by road type and time of day.

LITERATURE REVIEW

Although several studies \((1,2,3,4,5,6,7,8)\) have investigated the characteristics of work zone crashes, the results of these studies have not been wholly consistent. A brief summary of the results of some of these studies is given under the following sub-headings:

- Crash Rates
- Crash Severity
- Crash Location
Crash Rates

Hall (6) indicated that crash experience during construction increased by 26% compared with the same period in the previous year when there was no construction. Rouphail (9) showed that the crash rates during construction increased by 88% compared to the before period at long-term work zones, while the crash rates at short-term work zones were not affected by the roadwork. Two studies (2,10) revealed that the crash rates at work zones were higher than at non-work zone, while Nemeth (8) showed that the accident rates at work zones were lower than on those control sites without work zones. However, Nemeth stated that the difference was not believed to be very significant.

Crash Severity

Two studies (11,12) showed work zone crashes were more severe than other crashes, while two other studies (2,6) concluded the severity of work zone crashes was not significantly different from all crashes. Five studies (5,7,8,9,13) stated that work zone crashes were (slightly) less severe than all crashes.

Crash Location

Four studies (2,7,8,13) addressed the specific locations of crashes in work zones. Hargroves (7) found that most crashes occurred at the work area (combining the longitudinal buffer area and the activity area). Nemeth (8) concluded that 39.1% and 16.6% accidents occurred in longitudinal buffer area and activity area respectively. In another study (13), Nemeth used another set of location categories and showed that most crashes occurred at single Lane zones, crossover or bi-directional zones (Two Lane Two Way Operation). Goddin (3) indicated that 69% of the crashes occurred in the activity area.
Other Crash Characteristics

The results of several studies (2,3,5,6,7,8,9,11,13) indicated that Rear-end crashes were the predominant collision type at work zones. Three studies (2,6,12) indicated that multi-vehicle crashes were over-represented at work zones while three studies (6,7,11) indicated that heavy vehicles were over-represented in work zone crashes.

Summary

The literature review revealed inconsistent results for many of the studies with respect to several characteristics. This discrepancy among the studies may be due to several factors, including the number of crashes considered, the time period during which the crashes occurred and the types of highways considered and whether the crashes considered were all work zone related. This study has therefore taken these factors into consideration in building up the data used for the analysis.

METHODOLOGY

Data Processing

Information on each work zone crash that occurred from 1996 through 1999 in Virginia was obtained from the police crash report. A review of each report was first undertaken to ascertain that each crash selected for the study was work zone related. A total of 1484 crashes out of the 1939 obtained from the database were then selected for the study. The location of each crash was then identified and noted as one of the five areas of a work zone. These areas are:

1. Advance Warning Area
2. Transition Area
3. Longitudinal Buffer Area
(4) Activity Area

(5) Termination Area.

Figure 1 The Five Defined Areas of the Common Work Zone
These locations are shown in figure 1. In addition, information was obtained on the severity (Fatal, Injury, or Property Damage Only), the collision type (rear end, angle, sideswipe, fixed object), type of highway and time of day. Percentage distributions were then determined for the location of the crashes, the severity and the collision type. Each of these distributions was then determined for each road type, and time of day. Proportionality tests were then conducted to determine the significance of the distributions of these characteristics. A 5% significance level was used for all the hypotheses tested. The following null hypotheses were tested:

1. The proportion of crashes at each location is not significantly different from the proportion at the other locations
2. The proportion of each severity level is not different from the others
3. The proportion of crashes by severity is the same for all locations
4. The proportion of each collision type is not different from the other collision types

The above null hypotheses were then repeated for each road type and by time of day.

RESULTS

Location Distribution

The location distribution for all the 1484 work zone accidents is shown in figure 2. This figure shows that the activity area (area 4) is the predominant crash location in a work zone, followed by the transition area (area 2), the advance warning area (area 1), the longitudinal buffer area (area 3) and the termination area (area 5) respectively. The results of the proportionality test show that the proportion of crashes occurring at the Activity Area (Area 4) is
significantly higher than that at each of the other locations. The results also indicate that the proportions of crashes in the five areas are significantly different from each other.

**Figure 2  Location Distribution for All Work Zone Crashes**

**Figure 3  Road Type Distribution for All Work Zone Crashes**
In order to study the effect of highway type on these distributions, the highways were first classified as Interstate, Primary and Secondary, and then each road was further classified as urban or rural. In classifying the urban and rural roads, the Northern Virginia urban secondary roads were separated from the rest of the urban secondary roads as some urban secondary roads in Northern Virginia carry volumes that are as high as those on primary roads. Figure 3 shows the distribution of work zone crashes by road type. It should be noted, however, that it couldn’t be concluded that the urban interstate highways are more susceptible to work zone crashes as these crashes were not normalized for traffic volumes or the number of work zones on each type of road.

Table 1 shows the proportion of crashes by road type and location at the work zones. The results of the proportionality tests shown in table 2, indicate that the proportion of the crashes occurring in area 4 for interstate, primary or secondary roads is not significantly different from the proportion of the crashes in area 4 for all crashes combined. This indicates that area 4 is more susceptible to crashes regardless of the type of highways. It should be noted that only 24 crashes out of the 1484 occurred in the termination area (area 5). This indicates that the termination area is the safest area in a work zone.

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Number of Crashes</th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
<th>Area 4</th>
<th>Area 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Interstate</td>
<td>544</td>
<td>7%</td>
<td>17%</td>
<td>6%</td>
<td>69%</td>
<td>1%</td>
</tr>
<tr>
<td>Rural Interstate</td>
<td>159</td>
<td>14%</td>
<td>14%</td>
<td>7%</td>
<td>65%</td>
<td>0%</td>
</tr>
<tr>
<td>Urban Primary</td>
<td>339</td>
<td>7%</td>
<td>10%</td>
<td>4%</td>
<td>76%</td>
<td>3%</td>
</tr>
<tr>
<td>Rural Primary</td>
<td>206</td>
<td>18%</td>
<td>16%</td>
<td>5%</td>
<td>58%</td>
<td>3%</td>
</tr>
<tr>
<td>NOVA Urban Secondary</td>
<td>94</td>
<td>10%</td>
<td>5%</td>
<td>8%</td>
<td>72%</td>
<td>5%</td>
</tr>
<tr>
<td>NOVA Rural Secondary</td>
<td>2</td>
<td>0%</td>
<td>0%</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
</tr>
<tr>
<td>Other Secondary</td>
<td>140</td>
<td>14%</td>
<td>10%</td>
<td>1%</td>
<td>74%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Area 1 (Advance Warning Area)  Area 2 (Transition Area)  Area 3 (Longitudinal Buffer Area)  Area 4 (Activity Area)  Area 5 (Termination Area)

Table 1 Percentage Distribution of Crashes by Work Zone Location and Road Type
Severity Distribution

Severity distributions were obtained for all crashes at different locations and for different road types. Table 3 shows the severity distribution by location and road type. Figure 4 shows the severity distribution for all crashes. The results of proportionality tests indicate that the most prevalent severity type is Property Damage Only (PDO) for all road types except for “rural primary” and “other secondary” roads, where the proportions for injury and PDO accidents are not significantly different from each other.

<table>
<thead>
<tr>
<th>Road Type</th>
<th>Number of Crashes</th>
<th>Crashes Total</th>
<th>Percentage of Proportionality in Area 4 Crashes</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Crashes</td>
<td>1030</td>
<td>1484</td>
<td>69%</td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>480</td>
<td>703</td>
<td>68%</td>
<td>Accept Ho</td>
</tr>
<tr>
<td>Primary</td>
<td>377</td>
<td>545</td>
<td>69%</td>
<td>Accept Ho</td>
</tr>
<tr>
<td>secondary</td>
<td>173</td>
<td>236</td>
<td>73%</td>
<td>Accept Ho</td>
</tr>
</tbody>
</table>

Table 2 Proportionality Test Results between Crashes in Area 4 for Each Road Type and Crashes in Area 4 for All Crashes Combined (Area 4: Activity Area)

Table 3 Percentage Distribution of Crashes by Severity, Location and Road Type
The results of proportionality tests also indicate that the proportion of fatal crashes at each work zone area is not significantly different from the proportion of the fatal crashes in all crashes combined. Similarly the proportionality test results indicated that the proportion of fatal crashes on interstate, primary or secondary roads is not significantly different from the proportion of fatal crashes in all crashes combined.

**Collision Type Distribution**

Table 4 shows the distribution of crashes by collision type, location and highway type and figure 5 shows the distribution of all crashes by collision type. The collision types with percentages of 5% or less were combined together and categorized as “others”. The results of Proportionality tests indicated that RE (rear end) was the predominant collision type and FI (fixed object in road) was the least prevalent collision type among the five collision types examined. The results of the proportionality tests also indicated that the proportion of AN (angle) crashes is significantly higher than the proportion of SS (sideswipe in same direction) crashes.
However, the proportion of FO (fixed object off road) crashes is not significantly different from the proportion of SS (sideswipe in same direction) and AN (angle) crashes.

<table>
<thead>
<tr>
<th>Area 1 (Advance Warning Area)</th>
<th>Area 2 (Transition Area)</th>
<th>Area 3 (Longitudinal Buffer Area)</th>
<th>Area 4 (Activity Area)</th>
<th>Area 5 (Termination Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Crashes</strong></td>
<td><strong>Work Zone Location</strong></td>
<td><strong>AN</strong></td>
<td><strong>FI</strong></td>
<td><strong>FO</strong></td>
</tr>
<tr>
<td>Urban Interstate</td>
<td>544</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Rural Interstate</td>
<td>159</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>Urban Primary</td>
<td>339</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Rural Primary</td>
<td>206</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>NOVA Urban Secondary</td>
<td>94</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
</tr>
<tr>
<td>NOVA Rural Secondary</td>
<td>2</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Other Secondary</td>
<td>140</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Number of Crashes</strong></td>
<td><strong>Area 3</strong></td>
<td><strong>Area 4</strong></td>
<td><strong>AN</strong></td>
<td><strong>FI</strong></td>
</tr>
<tr>
<td>Urban Interstate</td>
<td>544</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Rural Interstate</td>
<td>159</td>
<td>0%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Urban Primary</td>
<td>339</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Rural Primary</td>
<td>206</td>
<td>1%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>NOVA Urban Secondary</td>
<td>94</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>NOVA Rural Secondary</td>
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<td>50%</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>Other Secondary</td>
<td>140</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

**Table 4 Percentage Distribution of Crashes by Collision Type, Location and Road Type**
Collision type distributions for areas 1 and 2 are shown in figures 6 and 7 respectively.

RE (rear end) crash is the predominant crash type in area 1. The high percentage of RE (rear end) crashes in area 1 may be due to increased speed variance in this area, caused by some drivers observing the speed reduction signs and reducing their speeds, while others do not. Although RE (rear end) crash is the predominant crash type in area 2, the percentage (26%) of the SS (sideswipe in same direction) crashes has increased to a level much higher that that for area 1. This increase in SS (sideswipe in same direction) crashes may be due to the increase in merging maneuvers necessitated by the reduction of the number of through lanes.
AN (Angle)   FI (Fixed object In road)   FO (Fixed object Off road)
RE (Rear End)   SS (Sideswipe in Same direction)

Figure 6  Collision Type Distribution for Work Zone Crashes Occurring in Area 1 (Advance Warning Area)

AN (Angle)   FI (Fixed object In road)   FO (Fixed object Off road)
RE (Rear End)   SS (Sideswipe in Same direction)

Figure 7  Collision Type Distribution for Work Zone Crashes Occurring in Area 2 (Transition Area)
Collision type distributions for areas 3 and 4 are shown in figures 8 and 9 respectively. The results of proportionality tests show that the percentage distribution of crashes by collision types is not significantly different for area 3 and 4. It is therefore reasonable to combine these two locations in carrying out crash analysis at work zones. As one moves from the transition area (area 2) to work area (combing areas 3 and 4), the proportions of RE (rear end) and SS (sideswipe in same direction) crashes decrease and the proportion of FO (fixed object off road) and AN (angle) crashes increase. This may be due to the increase of conflicts between traffic and the construction activities.

![Collision Type Distribution for Area 3](image)

**Figure 8** Collision Type Distribution for Work Zone Crashes Occurring in Area 3 (Longitudinal Buffer Area)
Collision type distributions for interstate, primary and secondary roads are shown in figures 10 through 12 respectively. The results of proportional tests indicated that RE (rear end) is the predominant collision type for interstate highways, followed by SS (sideswipe in same direction), FO (fixed object off road), AN (angle) and FI (fixed object in road). However, the proportion of SS (sideswipe in same direction) crashes is not significantly different from the proportion of FO (fixed object off road) crashes. Similarly the proportion of AN (angle) crashes is not significantly different from the proportion of FI (fixed object in road) crashes. For primary roads, RE (rear end) is also the predominant collision type, followed by AN (angle), FO (fixed object off road) and SS (sideswipe in same direction). However, the proportion of FO (fixed object off road) crashes is not significantly different from the proportion of SS (sideswipe in same direction) crashes. For secondary roads, RE (rear end) is also the predominant collision type, followed by AN (angle), FO (fixed object off road) then SS (sideswipe in same direction), BI (backed into) and PE (collision with pedestrian). In this case the proportions of FO (fixed object off road), SS (sideswipe in same direction), BI (backed into), and PE (collision with
pedestrian) crashes are not significantly different from each other except that the proportion of FO (fixed object off road) is significantly larger than the proportion of PE (collision with pedestrian). RE (rear end) crash is also the predominant type of crashes at these areas.

**Figure 10** Collision Type Distribution for Work Zone Crashes Occurring on Interstate

**Figure 11** Collision Type Distribution for Work Zone Crashes Occurring on Primary Roads
In order to test whether the proportion of a collision type is influenced by the type of highway, the proportionality test was conducted on the distributions by collision type for the different types of highways. The following results were obtained:

1. The proportions of RE (rear end) crashes on interstate and primary highways are significantly higher than the proportion of RE (rear end) crashes on secondary roads.
2. The proportions of AN (angle) crashes on primary and secondary roads are significantly larger than the proportion of AN (angle) crashes on interstates.
3. The proportion of SS (sideswipe in same direction) crashes for interstates is significantly higher than the proportions of SS (sideswipe in same direction) crashes on primary and secondary roads.
4. The proportion of BI (backed into) crashes on secondary roads is significantly higher than the proportion of BI (backed into) crashes on interstates.
(5) The proportion of FO (fixed object off road) crashes on interstates is significantly higher than the proportion of FO (fixed object off road) crashes on primary roads.

(6) The proportions of FI (fixed object in road) crashes on primary and secondary roads are not significantly different from each other.

In comparing urban with rural roads, the results of the proportionality tests indicated the following:

(1) The proportion of each collision type for urban interstates is not significantly different from that for the rural interstates.

(2) The proportions of AN (Angle), FI (fixed object in road), PE (collision with pedestrian) and RE (rear end) crashes for urban primary roads are not significantly different from those for rural primary roads, while the proportions of BI (backed into), FO (fixed object off road) and SS (sideswipe in same direction) crashes for urban primary roads are significantly different from those for rural primary roads.

**Severity and Collision Type Distribution by Time**

In order to determine the effect of time of day on the crash characteristics at work zones, the crashes were classified into six groups based on the time of day that the crash occurred. The following time periods were used: 6:00-10:00, 10:00-13:00, 13:00-16:00, 16:00-19:00, 19:00-22:00, and 22:00-6:00. The time ranges were selected to allow the evaluation of the effect of the peak volume periods. Figure 13 shows the distribution of the crashes by collision type for the 22:00-6:00 time period. This distribution is similar to those of the other time groups, in that RE crashes were the predominant crashes for all time zones. Also it was found out that most of the crashes occurred in area 4 for all time periods.

The results of proportionality tests also show:
(1) The proportion of AN (angle) crashes occurring during 22:00-6:00 in area 4 is significantly lower than the proportion for the other time intervals.

(2) The proportion of FI (fixed object in road) accidents occurring during 22:00-6:00 in area 4 is significantly higher than the proportion for the time interval of 10:00-19:00, but is not significantly different from those for other time intervals.

(3) The proportion of FO (fixed object off road) accidents occurring during 19:00-6:00 in area 4 is significantly higher than the proportion for other time intervals.

(4) The proportion of RE (rear end) accidents during 19:00-6:00 is significantly lower than the proportion for other time intervals.

(5) The proportion of SS (sideswipe in same direction) accidents is not significantly different between different time intervals.

Figure 13  Collision Type Distribution for Work Zone Crashes Occurring in Area 4 (Activity Area) from 22:00 to 6:00
SUMMARY OF RESULTS

- Activity area (Area 4) is the most prevalent accident location in a work zone, and termination area (Area 5) is the safest area in a work zone.

- For all the crashes studied, PDO is the predominant severity type, followed by injury and fatal. Fatal accidents comprise the smallest fraction of crashes.

- RE is the predominant collision type. The vast majority (83%) of the crashes occurring in advance warning area (Area 1) is RE (rear end). The proportion of SS crashes increase when the traffic moves from advance warning area to transition area (Area 2) and SS (sideswipe in same direction) crashes become the second largest proportion of crashes in the transition area. As one moves from the transition area (Area 2) to work area (combing Areas 3 and 4), the proportions of RE (rear end) and SS (sideswipe in same direction) crashes decrease and the proportion of FO (fixed object off road) and AN (angle) crashes increase.

- The crashes occurring in activity area (Area 4) during peak hours are less severe than those occurring during non-peak hours. There are more FO (fixed object off road) and less RE (rear end) accidents during nighttime (19:00-6:00) than during daytime (6:00-19:00). And there are less AN (angle) accidents during 22:00-6:00 than the other time.

CONCLUSIONS

The results of the study clearly show that the most dangerous area within a work zone is the Activity (Area 4). Therefore any countermeasure that will significantly reduce the crashes in area 4 will have a significant impact on safety in the work zone.

The predominance of rear end crashes in work zones, strongly indicate that a major causal factor for work zone crashes is speed related. Rear End crashes are mainly caused by
vehicles driving at different speeds, resulting in high speed variance. The implementation of a countermeasure that reduces speed variance or that causes drivers to drive at approximately the same speeds throughout the work zones, will therefore increase safety at work zones significantly. It should be noted that this does not necessarily mean lowering speed limit at the work zone, as a lower speed limit does not necessarily result in a lower speed variance.

ACKNOWLEDGMENTS

The authors thank the Virginia Transportation Research Council and the Virginia Department of Transportation for their support of this research, particularly Mr. Lewis Woodson from the Virginia Transportation Research Council.
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Figure 13. Collision Type Distribution for Work Zone Crashes Occurring in Area 4 (Activity Area) from 22:00 to 6:00
Incident Management Programs

In the United States

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Engineer of Traffic and Operations
Transportation Research Board
United States of America

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Pretoria, South Africa
20 -- 22 September 2000
Incident Management Programs in the United States

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Engineer of Traffic and Operations
Transportation Research Board
Washington, DC  USA

ABSTRACT: Traffic congestion has a daily impact on millions of motorists – both in terms of congestion and in terms of safety. To study congestion and develop countermeasures, the two general types of congestion must be addressed separately: recurring congestion, which occurs routinely at predictable times and locations, and non-recurring congestion, which occurs at random times and locations. This non-recurring congestion is typically caused by incidents (e.g., vehicle accidents, and breakdowns). It has been estimated that more than 60% of all urban traffic congestion in the United States is a result of traffic incidents and 20% of incidents are resulting from previous incidents. Consequently, the development of Incident Management programs has become an important component of traffic safety and operations management in the United States.

Incident Management is a systematic and coordinated program to detect and remove incidents and restore capacity as safely and as quickly as possible. The goal of Incident Management programs is to minimize the impact of incidents on traffic flow and thus reduce congestion and improve safety.

There are many Incident Management programs throughout the United States and they vary dramatically in scope, complexity, and cost. The purpose of this paper is review the characteristics of the various Incident Management programs that have been implemented in the U.S. and report on lessons learned from our experiences.

THE PROBLEM: TRAFFIC CONGESTION

In the United States highway congestion is a daily occurrence in all large metropolitan areas. It is a constant source of frustration and agitation for millions of commuters and travelers. Road Rage and Aggressive Drivers are new terms that have been added to our language in an attempt to describe this driver dissatisfaction. These terms are now used regularly by our media, politicians, and highway agency personnel to describe the behavior of drivers reacting to the congestion levels being found on our roadways. On almost a daily basis we hear a report of some aggressive driving accident or a road rage altercation.

Increasingly, highway congestion is becoming a burden on the U.S. economy, productivity, and quality of life. Congestion has grown throughout the 1980s and 1990s, leading to a reduction in overall highway performance. Once an urban problem -- congestion now affects all areas of the country. In 1981, 25% of urban highways were classified as congested. By the mid-90s that proportion had risen to over 45%.

As environmental concerns, land use, and budget constraints make building new roads more difficult, we are not likely to build ourselves out of the situation. In the U.S., since the mid-60s, urban Interstate vehicle-miles traveled has increased three times as fast as the construction of highway miles. In addition, the following trends will continue perpetuate this imbalance between demand and capacity:
Incident Management Programs in the United States

- The advent of the two-worker households where both spouses are now employed has introduced new work-trips for the spouse and other non-work trips to day-care, food stores, restaurants, etc.

- The continued movement of population and employment from central cities to suburbs and exurbs has made congestion not just a downtown problem, but a metropolitan and regional problem.

- There has been a large increase in personal travel which when coupled with the wider dispersion of jobs within a region has spread congestion impacts from the peak-hour to the peak-period that could last several hours each day.

- The introduction of "just-in-time" distribution goods and materials to a geographic dispersion of recipients, and the advent of e-commerce and the resultant delivery of purchases as turned our highways into rolling warehouses and retail stores.

- There is a shift in economic growth towards the so-called "sun-belt" which will spread congestion into smaller cities that were only minimally congested before.

Thus we must learn to more efficiently and effectively manage the roadway capacity that we have -- and incident management is one of the traffic management tools that the United States is actively deploying.

Traffic incidents are a big contributor to congestion. The Texas Transportation Institute estimates that currently, incident related delay accounts for between 50 and 60 percent of total congestion delay in our urban areas -- and it is expected to worsen to 70 percent or greater by the year 2005 -- costing the U.S. public in excess of $75 billion in lost productivity and 8.4 gallons of wasted fuel annually.1

TWO TYPES OF CONGESTION -- RECURRING AND NON-RECURRING

Congestion is the result of a situation where the demand exceeds the roadway capacity. There are two types of congestion:

Recurring congestion is the predictable delay caused by the high volume of vehicles using the highways. Contributors to this recurring congestion includes, excess traffic demand to capacity; heavy entering, or exiting ramp volumes; and poor roadway geometrics.

The other type of congestion is the non-recurring congestion or incident congestion, which is the unpredictable delay caused by highway incidents.

WHAT IS AN INCIDENT?

An incident refers to any random event that reduces safety and slows traffic. It can be a crash, a vehicle breakdown, a spilled load, adverse weather conditions, debris on the roadway, or any other unusual event that reduces the effective capacity of the roadway and impedes the normal flow of traffic. It is estimated that this congestion annually costs the U.S. more than $70 billion in lost productivity and eight billion gallons of wasted fuel.

Incidents create bottlenecks, which restricts vehicle flow. The amount of congestion caused by the incident depends on the duration of the incident, the number of lanes closed, and the volume of traffic at the time of the incident.

**Incident Characteristics**

As mentioned, an incident is a random event that is unpredictable in relation to its time and location. Studies of incident types and duration suggest that about 80-85 percent of incidents are disabled vehicles; five to 10 percent are accidents; and 10-15 percent are related to emergency maintenance work, debris on roadway, and other similar events.

Table 1 shows a summary of all types of incidents occurring on a section of Highway 401 in Toronto, Canada.

<table>
<thead>
<tr>
<th>Incident Type</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>32</td>
</tr>
<tr>
<td>Flat Tire</td>
<td>18</td>
</tr>
<tr>
<td>Accident</td>
<td>15</td>
</tr>
<tr>
<td>Overheat</td>
<td>8</td>
</tr>
<tr>
<td>Out of Gas</td>
<td>7</td>
</tr>
<tr>
<td>Abandon</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 2 provides a comparison of the differences in characteristics between Minor and Major incidents.

<table>
<thead>
<tr>
<th></th>
<th>Minor Incidents</th>
<th>Major Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>80% of Incidents</td>
<td>20% of Incidents</td>
<td>Area/Corridor-wide Impact</td>
</tr>
<tr>
<td>Local Impact</td>
<td>One Agency</td>
<td>Multiple Agencies - A Response Plan is Activated</td>
</tr>
</tbody>
</table>

**Incident Impacts**

**Safety**

One of the biggest impacts of incidents is on safety. Approximately 20% of all incidents are caused by previous incidents. Of these secondary crashes, approximately four percent of motorway fatalities resulted from “Hitting a Vehicle on Shoulder.” Thus, an important element in an incident management program is the quick clearance and, where necessary, the diversion of traffic.

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Traffic Congestion

Another incident impact is traffic congestion resulting from incidents. As was mentioned earlier, more than 60% of delay on urban freeways is caused by incidents. The California Department of Transportation estimated that for every minute of incident duration -- 4 to 5 minutes of recovery time is required.

Table 2 is a summary of the capacity reductions associated with the most common types of incidents. This table illustrates the dramatic effects even one stalled vehicle can have on roadway capacity. These capacity reductions result in congestion, delay, and secondary accidents.

<table>
<thead>
<tr>
<th>Incident Type</th>
<th>Capacity Reduction (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Flow - 3 lanes</td>
<td>--</td>
</tr>
<tr>
<td>Stall - 1 lane blocked</td>
<td>48</td>
</tr>
<tr>
<td>Non-injury accident - 1 lane blocked</td>
<td>50</td>
</tr>
<tr>
<td>Accident - 2 lanes blocked</td>
<td>79</td>
</tr>
<tr>
<td>Accident on shoulder</td>
<td>26</td>
</tr>
</tbody>
</table>

WHAT IS INCIDENT MANAGEMENT?

Incident management is a planned and coordinated process to detect and remove highway traffic disruptions and restore capacity as safely and as quickly as possible. In many locations, it is also multi-agency and multi-jurisdictional. Efficient and coordinated management of incidents reduces their adverse impact on public safety, traffic conditions, and the local economy.

An incident management program represents a coordinated and planned approach to defining the necessary resources and required procedures to facilitate an efficient response to the occurrence of an incident and restoring the traffic to normal operation as quickly and as safely as possible. Incident management consists of six components:

1. Detection
2. Verification
3. Response
4. Site Management
5. Traffic Management and Motorist Information
6. Clearance and Recovery

The effectiveness of an incident management program depends on how well these six stages are managed.

Incident Detection

Incident detection is the determination that an incident has occurred. In the U.S. most incidents are detected within 5-15 minutes of occurring. Incident detection methods include routine police patrols or service patrols; call boxes located along highways, citizen band radios,

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3 Roper, David H., Freeway Incident Management, National Cooperative Research Program, NCHRP 20-5, Washington, DC.
automated incident detection based on traffic surveillance, CCTV cameras, aerial surveillance, and increasingly cellular phone calls from motorists.

Table 3 summarizes the Los Angeles, California experience on the various detection methods that were used to identify that an incident has occurred.

<table>
<thead>
<tr>
<th>Detection Method</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Phones</td>
<td>54</td>
</tr>
<tr>
<td>Call Boxes</td>
<td>36</td>
</tr>
<tr>
<td>Service Patrols</td>
<td>3</td>
</tr>
<tr>
<td>Police</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

**Incident Verification**

Incident verification is the determination of the precise location and nature of the incident. Verification is a necessary step to prevent the deployment of equipment and personnel to false or inaccurate reports. With accurate information about an incident, appropriate personnel and resources can be dispatched to the scene. Verification methods include at-site verification by dispatched personnel such as service patrols or police patrols; compilation and synthesis of information from multiple cellular telephone calls; aerial surveillance by airplane or helicopter, and the use of CCTV cameras in those areas that have video surveillance capabilities.

**Incident Response**

Incident Response is the initiation of a planned strategy for the deployment of the personnel and resources to the verified incident scene. Agencies have found that it is important to develop a standard set of interagency response plans tailored to the various types of incidents that may occur. This leads to improved response times with optimum equipment and personnel dispatched to the incident scene. Over-responding to incidents (dispatching more resources than is necessary) or under-responding (not sending enough resources) results in poor response effectiveness and increased costs.

Almost all urban areas have emergency response plans for catastrophic incidents, especially those involving hazardous materials.

**Incident Site Management**

Site management is the management of the equipment and personnel to quickly remove the incident and minimize the impact on traffic flow.

For major incidents, site management generally necessitates the coordination of activities by various personnel and equipment from different responding agencies (transportation, police, fire, emergency medical services, towing, etc.). In such cases, agencies have found it important to establish an "incident command system" to ensure a coordinated and decisive reaction to the incident clearance. The incident command system is a set of predefined hierarchy of roles and responsibilities for each agency for incident management command, operations, and communications.

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Traffic Management and Motorist Information

Traffic control at an incident scene is an important element in ensuring the safe and efficient incident clearance. This component involves the traffic control at the scene including: lane closures and openings, establishing and operating alternate routes; traffic diversion when necessary to reduce traffic volumes through the incident scene; parking of emergency vehicles and ensuring the safety of incident victims, motorists, and emergency personnel.

Motorist information is the deployment of various mechanisms for communicating incident site traffic conditions to motorists. If drivers are kept informed they will have a greater tolerance for the delays and they can plan for their added travel time. Thus, it is important to provide methods of communicating real-time information to motorist for either pre-trip planning or en-route traffic updates. Typically this includes: Changeable message signs; portable signing; highway advisory radio; and communication with "traffic report" information sources (radio and television stations, Internet, etc.) to warn drivers in advance of their arrival at the scene.

Incident Clearance and Recovery

Incident clearance and recovery is the safe, efficient, and timely removal of any broken-down vehicle, wreckage, debris, or spilled material from the roadway and its shoulders and then the restoration of the roadway to its full capacity. Incident clearance is typically the most time-consuming step in the incident management process -- taking generally at least twice as long in duration as all the other steps combined.

Incident Management Is Multi-Agency, Multi-Disciplinary

Incident management is an important operations function of state, regional, and local transportation agencies; law enforcement agencies; fire and rescue agencies; tow operators; hazardous material cleanup services; traveler information providers; and a series of other agencies that support these primary agencies. For a major incident, the personnel and equipment from these agencies must be mobilized, leveraged, and managed collectively within a very short period of time. In addition, at the incident site, the priorities of the road agencies, police, fire, and rescue personnel are frequently conflicting. Thus, it is important to proactively seek and maintain multi-agency planning and coordination to ensure the full cooperation and support of all agencies for the incident management programs and activities.

Traffic Management Teams

To ensure that all agencies cooperate effectively, interagency relationships must be developed prior to a major incident. To facilitate this cooperation, many areas in the United States have developed "traffic management teams" with membership from all agencies having an incident management responsibility. Traffic management teams are normally permanent groups which meet regularly to plan, coordinate, evaluate, and improve incident response and address other traffic problems as well. Thus, when an incident does occur, they have a plan -- and they execute it with the full cooperation among all of the organizations involved.

Agencies having an interest and involvement in incident management include:

State, Regional, and Local Transportation Agencies

This includes the departments of transportation and highway agencies that operate and maintain the road network in the region. Transportation agencies typically focus their response priorities on the restoration of normal traffic flow and minimization of delays -- which frequently is at cross-purposes with other responding agencies.
State, Regional, and Local Enforcement Agencies

This includes the various police agencies having responsibilities for public safety and enforcement in the region. Their first priority is the safety of motorists, other responders, and the public. Typically, their secondary emphasis is on restoring the traffic flow.

Fire and Rescue Agencies

This includes fire, emergency medical services, and support response agencies -- be they public, volunteer, or private. Like the enforcement agencies, their first priority is the safety of motorists, victims, and other persons. Restoring the flow of traffic is of secondary importance.

Hazardous Material Cleanup Services

This includes public agency HAZMAT containment groups and private companies that provide cleanup services for HAZMAT incidents.

Quick and timely response to a HAZMAT incident can significantly reduce environmental damage and save many hours of motorist delay. Therefore, many agencies are training their incident response personnel to accurately identify the presence and nature of the hazardous material involved and providing equipment and material to contain minor spillage and protect the incident scene.

Since working in and around hazardous materials at HAZMAT incidents requires expert knowledge and experience, specialized HAZMAT contractors are used by all major urban areas in the U.S.

Towing and Recovery Operators

Towing and recovery operators clear the roadway of disabled vehicles and assist in the restoration of full capacity to the roadway. In the U.S., most public agencies do not provide towing and recovery services, but contract with private providers to perform this function.

Public and Private Traveler Information Providers

This includes public agencies and private companies that collect, process, and disseminate traffic information using television, radio, Internet, highway advisory radio, and changeable message signs.

COST-EFFECTIVENESS OF INCIDENT MANAGEMENT

Incident management programs in various forms are currently in place in over 50 locations throughout the United States. Experience from these programs has shown that by improving the management of incidents -- significant benefits to motorists can be obtained from the reduced vehicle delays and enhanced safety. Also, these delay savings and the resultant increased travel speeds can considerably reduce vehicle emissions. An analysis of a comprehensive incident management effort, complete with service patrols and major incident response teams, can yield benefit/cost ratios as high as 17 to 1.6

This cost-effectiveness of incident management programs has justified the continuation of existing programs and the initiation of new programs.

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Incident Management Programs in the United States

For example:

- The Houston, Texas TranStar System has attributed annual delay savings of over 570,000 vehicle-hours with economic value of $8.4 million and reduction of hydrocarbon emissions by 91kg/day.
- The I-95 Traffic and Incident Management System in Philadelphia, Pennsylvania, has reduced freeway incidents by 40% and cut freeway closure time by 55%.
- San Francisco, California Freeway Service Patrol is assisting approximately 16,000 drivers/year.

TYPES OF INCIDENT MANAGEMENT PROGRAMS IN THE UNITED STATES

Each of the incident management programs in the United States have a unique combination of features that have been tailored to meet the needs of their particular situation. However, one fact is seems common to all -- the more successful programs have a "champion" that has pushed the incident management concept to develop support within their and other agencies.

In general, most agencies begin with low cost initiatives and build upon their successes to evolve over a number of years into larger, multi-agency, multi-technology programs.

Today, incident management programs in the United States range in scope from low-cost efforts like push-bumpers on police cars to high-cost systems with traffic management centers, video-surveillance, etc.

Low-Cost Incident Management Programs

Incident management programs can be accomplished with very little cost and still obtain significant results and high positive public perception. Examples of these low-cost programs include:

Incident Management Trailers

An important first step that can be taken with very little funding is to assemble a trailer containing detour signs, cones, flares, etc. which can be quickly transported to an incident scene and provide equipment for traffic control during the duration of the incident.

Route Diversion Plans

The deployment of alternate route plans are a valuable traffic management strategy for minimizing the effect of a major incident on traffic flow by reducing the demand at the incident site through the diversion of traffic from the main route.

Most agencies in the U.S. have developed some form or route diversion plans. They range in scope from detours at specific spots to development of system-wide diversion plans. They are developed to address a wide range of incidents, including, severe crashes; acts of nature (flooding, hurricanes, earthquakes, etc.); nuclear disasters; and special events (non-recurring sporting events and music concerts, etc.).

Some agencies have permanently mounted route diversion signing using color codes or similar techniques. For example, the City of Dayton, Ohio has installed permanent detour signs for Interstate-75 closure and diversion plans. The signs are normal traffic control signs (Speed Limit, Hospital, School Area, etc.) that are horizontally hinged at the middle and contain the detour.

signing information on the backside. When a diversion route is put into effect, the signs are flipped down and the detour route guidance is displayed.

**Push Bumpers**

Some agencies have installed push bumpers on the front of their police or service patrol vehicles for removing disabled vehicles quickly from the traveled lanes. This requires minimal funding and has a very high positive public perception.

**Accident Investigation Sites**

Accident Investigation Sites are special designated and signed areas off the freeway where drivers involved in non-injury related accidents can exchange information and the police can complete the necessary accident report forms. These areas are located so that the vehicles involved in the accident and the police and towing vehicles are out of the site of the freeway traffic. This eliminates what we call "rubber necking" which is a major cause of freeway congestion at accident scenes. Experience with accident investigation sites in Houston, Texas shows a benefit cost ration of 28 to 1 or higher.

**"Move It" Programs**

To help remove the perception that drivers must not move their vehicles from the roadway after a crash until the police have arrived -- some states have developed "Move It" public information programs. These programs stress the need to move vehicles quickly from the traveled lanes either to the shoulder or to accident investigation sites. This helps to quickly restore the traveled lanes to normal traffic flow and reduce secondary accidents.

**Freeway Service Patrols**

The freeway service patrol's function to satisfy the incident detection, verification, response, and removal components of incident management in the event of a minor incident.

U.S. experience is that in areas without service patrols, police vehicles on normal patrol duties spend a significant amount of their time assisting with clearing disabled vehicles from the roadway. In areas with service patrols, the patrol vehicles are staffed with non-police personnel -- which frees up uniformed officers for other essential police functions.

Studies have shown that freeway service patrols (also called courtesy patrols, highway helper patrols, etc.) are cost-effective for mitigating the effects of minor incidents such as vehicle breakdowns. Their primary objectives are to minimize the duration of incidents by fast removal -- thus reducing the risks to motorists and response personnel. Estimates from various agencies with these programs indicated that 70 to 90 percent of all incidents are handled in 30 minutes or less.

Typically service patrols operate as a mobile watch on the freeways searching for accidents or vehicle breakdowns. They will assist by pushing or towing the vehicles from the roadway. For stranded motorists they will help in either fixing the problem (adding petrol or water, helping replace a tire, minor repairs if possible, etc.) or calling for a tow-truck.

Some agencies station a service patrol vehicle at critical locations (bridges, tunnels, etc.) during the peak hours to ensure the rapid removal of a broken down vehicle and quick restoration of normal traffic flow.

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Technology Improvements in Accident Data Collection

To more quickly investigate accidents and restore normal traffic flow, many agencies are turning to technology improvements to more quickly collect the crash data for accident reporting. This includes using surveyors "total station" transits to more rapidly obtain measurements at fatal accident scenes; in-vehicle and hand-held computers for collecting driver and vehicle information; and digital cameras for recording the accident scene.

Medium-Cost Incident Management Programs

As agencies gain experience and political and public support grows, agencies begin to initiate more costly programs. Examples of these medium-cost programs include:

Major Incident Response Teams

An expansion from the service patrols is major incident response teams (MIRT). An MIRT is the combination of law enforcement, traffic engineering, maintenance, and other relevant personnel, which collectively manages a major incident. The team is responsible for assessing the situation at each incident and using pre-developed response plans and members knowledge and experience in making decisions on how best to handle the incident.

A major incident is defined differently by agencies -- but it general it is when an incident is blocking two or more freeway lanes and it expected to last for two hours or longer.

The role of the MIRT is to decide:

- Does the incident require an specialized handling or vehicles (HAZMAT or oversize tow-trucks, etc.);
- Is a detour required and where traffic will be detoured;
- How and when will the wreckage will be cleared;
- How and when will repairs to the roadway will be made;
- When can roadways be partially or fully re-opened.

Generally an on-site command post is established at the accident scene. Each responding agency will assign a person to the command post to ensure a coordinated incident response.

Many agencies have developed specialized response vehicles for deployment to the accident scene. These vehicles are equipped with lights; traffic control devices; multiple communication devices (multi-band radios, cell-phones, walkie-talkies, etc.) to communicate with the various responding agencies; absorbent material for liquid spills; pumps for emptying fuel from vehicles; inflation devices or hooks and winches for righting overturned vehicles; etc.

Another aspect of MIRT is the assignment of specific personnel to the response teams. Because of the specialized nature of response techniques for major incidents, agencies assign specific personnel to the response teams. These team members are on-call 24 hours a day and go into action when an incident requires major response. In some agencies, teams operate similarly to a volunteer fire department as some members take vehicles and equipment home with them for more rapid deployment when an incident occurs.

Because of the specialized knowledge that is required for a response to a major incident, specialized training for response team members is needed. This would include training on identification of hazardous materials and appropriate handling; operation of equipment; specialized traffic control at incidents; advanced first aid; CPR; fire fighting; basic auto extraction; radio communications; heavy equipment use; etc.
Cellular Telephone Incident Reporting Number (E-11)

The growing number of cellular mobile telephones has created the opportunity to greatly decrease the time it takes for traffic incidents and other emergencies to be reported to police and emergency response agencies. To organize this reporting mechanism and to maximize the opportunity to reduce total response time by correctly connecting the reporting caller directly to the appropriate agency, some areas have developed a dedicated E-11 telephone number for reporting. To inform the motoring public of the availability of this reporting mechanism, public education brochures are distributed to the public (frequently by the cellular telephone company to their subscribers). In addition, large motorist information signs are installed at various locations along the highway with the E-11 telephone number listed for reporting accidents and incidents.

There have been a number of recent developments in the United States related to the use of cellular telephones for incident reporting:

1) A nation-wide E-11 telephone number was approved this past summer for reporting highway-related information. This number is still in its infancy and deployment will begin soon.

2) The U.S. Federal Communication Commission (FCC) has announced that they will soon require that all emergency reporting calls originating from a cellular telephone be automatically locatable within a close proximity to the point of origin. This is reduce the number of inaccurate reports that are being received because many persons reporting an emergency by cellular telephone do not know their exact location or are highly stressed and provide inaccurate information. A number of different technologies (handset or infrastructure based) are being evaluated to meet this requirement and some operational testing is being conducted by some agencies.

3) There is a growing public sentiment that cellular telephone operation showed be prohibited in moving vehicles. As a result, a number of politicians in the U.S. have introduced legislation to that effect.

Telephone Call Boxes

Many agencies have installed telephone call boxes along the roadside, which connect directly to the responding agency. These call boxes are very popular with the public, especially in rural areas where cellular telephone coverage may be limited or non-existent. One advantage of the call-boxes is that the receiving agency knows exactly where the call has originated for rapid deployment.

High-Cost Incident Management Programs

At the far-end of incident management programs are the high-cost initiatives. These generally have surveillance over a wide-area and are "system" based in that they combine elements of command and control centers, detection and surveillance technology, and motorists information technology

Traffic Operations Centers

A traffic operations center (TOC) serves as a central information processing and command and control site. The TOC collects and analyzes information, manages communications amongst response agencies during an incident, and controls traffic through the information provided to the public regarding incident location, extent, and detour routes when appropriate.

TOCs generally take a large commitment in terms of funding and organizational support. However, once established, they help to sustain and expand the incident management program within a region.
Staff located at a TOC can be from a single agency or multiple agencies. When multiple agencies are in residence, the TOC helps build institutional relationships to ensure a cooperative response to major incidents.

Typically, TOC systems are custom designed for a particular location and often include:

- Dynamic wall-map displays, projection-type graphics, or video-walls of monitors,
- Extensive surveillance techniques and traffic information provided by the system detectors,
- Detailed status reporting on various measurements of effectiveness,
- Multiple communication techniques,
- Ramp metering controls,
- Controls for real-time motorist information that is to be displayed on changeable message signs,
- Full-time staffing or monitoring by personnel.

Incident Detection and Verification Techniques

There are many different technologies available for incident detection and verification. In the United States, each agency selects those that are appropriate for their region. Some of the technologies have already been discussed in this paper. Others include:

Automatic Surveillance Techniques

In addition to the cellular or call-box reporting, these high-end systems employ advanced detection technology which can automatically identify that an incident has occurred by changes in the traffic stream.

Electronic surveillance: Requires the use of sensors placed along or adjacent to the roadway to detect the presence of vehicles and automatic processing of this data to analyze traffic flow data for identifying congestion. The sensor types include induction loops, magnetometers, microwave, infrared, sonic, etc. which can continuously monitor the roadway section and provide rapid detection of incidents.

Closed-circuit television (CCTV): Use of television type cameras placed along the roadway for video surveillance. The CCTV serves as an effective verification technique allowing rapid determination and nature of the incident.

Automatic Vehicle Identification (AVI): This is the use of transponder equipped vehicles acting as probes in the vehicle stream to measure travel time and speed between monitoring stations. AVI does not require detectors in the pavement but does require a sufficient number of probe vehicles to get accurate segment and system-wide performance measures. A potential side benefit to the FCC requirement that all cellular telephones be locatable is that some of the infrastructure based locating technology would have offer as a side benefit the ability to use an operating cellular telephones as a probe by monitoring the change in its location.

Other Surveillance Techniques

Non-technology based surveillance techniques include:

Fixed observers: Use of observers positioned on towers or buildings along the
highway to observe incidents. This technique may be useful for interim measures or as a starting point for a detection system.

**Aerial Surveillance:** Use of helicopters and small planes to report incidents. This technique is useful for wide-area detection, incident verification, and evaluation of the effectiveness of the implemented traffic control plan as there is the capability to see far down the roadway. The aerial surveillance can be used as a regular surveillance vehicle or as a response vehicle to aid incident scene management. However, this technique is costly in terms of capital and operating expenses.

**Advance Motorist Information Techniques**

Motorists need to receive information on traffic conditions and suggested detours in a timely manner. When provided with timely and accurate information motorists will also have a greater tolerance for the delays and they can plan for their added travel time. However, for the information to be effective, it is very important that the information be credible, in terms of both accuracy and timeliness.

As discussed earlier, motorist information is the deployment of various mechanisms for communicating incident site traffic conditions to motorists for either pre-trip planning or en-route traffic updates. Advanced techniques typically includes: Changeable message signs; highway advisory radio; and communication with "traffic report" information sources (radio and television stations, cable TV stations, information kiosks in public areas, Internet, etc.) to warn drivers in advance of their arrival at the scene.

Other information techniques include:

- Some agencies have a traffic reporter on-site in their TOC during peak-periods or during major incidents to supply traffic reports to local radio and television stations.
- Some agencies feed their video-surveillance pictures to television stations, cable TV stations, and Internet sites for motorists access for pre-trip planning.
- Private subscription services are broadcasting information to subscribers via alphanumeric pagers
- Some cellular telephone companies provide a number for motorists to call to obtain traffic information
- In the not too distant future, in-vehicle route guidance will electronically link traffic data with dynamic trip routing via map displays mounted on automobile dashboards. A two-way communication link will transmit vehicle trip destinations and will in turn receive data on congestion due to incidents or other causes along the route.

**SUMMARY AND CONCLUSIONS**

The terms 'recurrent and non-recurrent are commonly used to categorize traffic congestion on the highway system. Recurrent congestion occurs routinely at times and locations that are fairly predictable and relatively constant. The non-recurrent congestion is generally the result of a temporary reduction in the roadway capacity due to an accident, maintenance activities, etc. In the United States, analysis indicates that the non-recurrent congestion is and will continue to be the bigger problem facing urban areas -- accounting for over 70% of the congestion by 2005.
The management of non-recurrent traffic congestion is difficult because neither the location, the time, the severity, or the cause of the congestion is known in advance of the occurrence. Thus incident management programs are essential for dealing with this unexpected congestion.

Incident management is a planned and coordinated process to detect and remove highway traffic disruptions and restore capacity as safely and as quickly as possible.

Incident management programs consist of six components:

- Detection
- Verification
- Response
- Site Management
- Traffic Management and Motorist Information
- Clearance and Recovery

Incident management is an important operations function of state, regional, and local transportation agencies; law enforcement agencies; fire and rescue agencies; tow operators; hazardous material cleanup services; traveler information providers; and a series of other agencies that support these primary agencies. For a major incident, the personnel and equipment from these agencies must be mobilized, leveraged, and managed collectively within a very short period of time.

Incident management programs in various forms are currently in place in over 50 locations throughout the United States. Experience from these programs has shown that by improving the incident response and clearance times -- significant benefits to motorists can be obtained from the reduced vehicle delays and enhanced safety. Also, these delay savings and the resultant increased travel speeds can considerably reduce vehicle emissions. An analysis of a comprehensive incident management effort, complete with service patrols and major incident response teams -- can yield benefit/cost ratios as high as 17 to 1.

Lessons Learned

Important lessons can be learned from the U.S. experience. In this paper, a number of different deployment strategies that have been used for incident management programs have been identified. However, the following are important lessons learned from the many successful systems.

Assign A Full-Time Person

Incident management does take resources to be successful. An essential resource is the availability of a full-time person specifically assigned to incident management. This person will be the "champion" for incident management and will be responsible for developing and maintaining incident response plans; traffic control and detour route plans; coordination amongst agencies; etc.

Communicate With Partner Agencies

Incident management is multidisciplinary involving many agencies with different goals and objectives at an incident site. Almost every problem can be resolved with established lines of communication between agencies.
Walk Before You Run

Experience has shown that it is very difficult to jump right into the high-cost, high-technology programs. Start small and build upon a record of success and transition into additional levels of activities as resources and support allow.

Anything Will Be An Improvement

If you do not currently have an incident management program -- anything you do should improve the situation. Without an incident management program in place, all remedial steps taken to respond to the incident are being done sequentially. That is, the police agency is called; they investigate and call a tow-truck and an ambulance; the highway department is then called too clean-up the scene and so on.

With an incident management program almost everything will be accomplished in parallel and each agency will perform their jobs concurrently -- thus reducing the response and recovery period resulting in an improvement in safety through the reduction of secondary accidents and a more timely restoration of the highway to normal traffic flows.

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Session 10  Traffic Engineering for Increased Mobility and Safety

Accident occurrence in Tram Traffic
_Jochen Korn, Werner Schnabel_

Simulation of intersection approaches with random and uniform arrival patterns
_Joseph C Oppenlander_

Crash reductions following installation of roundabouts in the United States
_Bhagwant Persaud_

Safety risks at traffic light installations
_Uwe Frost_

Assuring safe roadsides in urban and suburban areas
_K. Opiela_
ACCIDENT OCCURRENCE IN TRAM TRAFFIC

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Summary

This study deals with an analysis of the tram accident occurrence in Dresden in 1995 and 1996. The total length of the tram network is about 129 km. More than 70% are road-level tracks, almost 20% are separate tracks and nearly 10% are independent tracks. More than 1000 tram accidents happened in each examined year. About 25% were accidents with personal injury. More than 90% were not caused by tram drivers but by drivers of other vehicles involved. About 80% of the accidents happened on road-level tracks. Within the tram network more than 70 accident black spots were found. For each of them at least five accidents in tram traffic per year are recorded. An evaluation of these accident black spots has shown different typical track-road combinations with increased risk of accidents. Different measures to improve safety in tram traffic are recommended.

Introduction

Public transport is an important aspect of urban traffic in German cities. Trams and light-rail rapid transits are passenger transport modes with high capacity, comfort and safety. Reliability and punctuality of public transport means are well known. However, the specific accident occurrence as well as the related costs for public transport companies and for the public in general are often not taken into account. This fact gave rise to investigations into the accident occurrence in public transport at the example of tram traffic in the city of Dresden.

The public transport company in Dresden is the Dresdner Verkehrsbetriebe AG (DVB AG). The accident statistics of the DVB AG contain different groups of accidents in tram traffic (1). Nearly all of the accidents belong to the groups collision and person accident. If a tram and another vehicle hit each other, it is indicated as a collision. If passengers in the tram or
pedestrians out of it are injured, it is indicated as a *person accident*. However, reality shows that person accidents are accidents with passengers in trams nearly exclusively. Both kinds of accidents may involve either property damage or personal injury. This paper focusses on *collisions* in tram traffic.

**The Tram Network in Dresden**

While the Dresden town area had nearly 467,000 inhabitants in 1996, the catchment area of the DVB AG amounts to over 566,000 inhabitants (7). The tram network in Dresden has a total length of nearly 129 km (5). The share of single track sections is about 17 km (less than 14%). The share of double track sections is about 112 km (more than 86%).

![Figure 1: Tram network in Dresden](image)

Different sorts of tracks are given in the tram network of Dresden. Road-level tracks (used by trams and other vehicles as a mixed mode street) make up the by far largest share (92.1 km or 71% in 1996). Separate tracks (used only by trams, located next to roads) (24.7 km or 19%) have a share twice that of independent tracks (used only by trams, located away from roads) (12.4 km or 10%). Figure 1 shows the development of the proportion of road-level tracks on the one hand and separate and independent tracks on the other hand (4). The future of track design will bring about a shift towards separate and independent tracks.
Accident Occurrence in Tram Traffic

While figure 2 shows the total number of accidents in road traffic in Dresden (4), table 1 gives an overview over the accident occurrence in tram traffic. More than 80% of accidents belong to the accident group *collisions*. More than 90% of the collisions in turn are accidents involving property damage.

![Figure 2: Total number of road accidents in Dresden](image)

It becomes immediately obvious, that track sections with road-level tracks show distinctly more accidents than other track types. However, it is important to mention in this context that the share of road-level tracks of the total length is above 70%. The accident density (accident to stretch ratio) of separate tracks is not much lower than that of road-level tracks. According to accidents with personal injury, the accident density of separate tracks is about three times higher than that of road-level tracks. This shows that a high proportion of road-level tracks in a tram network is not inevitably related to a frequent accident occurrence in tram traffic.

The accident statistics of Dresden Police Headquarters (6) show right off that less than a third of tram accidents were reported to the police (bottom of table 1). Many accidents are relatively harmless (trivial damages), about which the police is not informed. Calling the police would possibly delay clearing the accident location and impede the transport operations of trams and vehicles longer than necessary. In this case, an accident report is often made by the tram driver.
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Abbreviations:
A accidents
AD accident density in accidents per km
PD property damage
PI personal injury
A(DPH) accidents reported to Dresden Police Headquarters

Table 1
Data of accident occurrence in tram traffic in Dresden

A catalogue for sorting the accident causes is used in the accident data base of the DVB AG, which distinguishes 22 accident causes (1). The distribution of the main accident causes is shown in table 2. This table includes only those causes that significantly influence the accident occurrence. Not keeping the *sideways distance* is a dominant cause for accidents which are caused by tram drivers. The cause *rear end collision* has also a relatively large share. In accidents that are caused by drivers of other vehicles involved the cause *right of way* is predominant. It is followed by the cause *sideways distance*. In comparison to that, figure 3 shows the distribution of the main causes of general accidents in road traffic in Dresden (4).
Concerning the temporal distribution of tram accidents it can be pointed out that most of the accidents occur in autumn or winter, on weekdays in the afternoon between 4 and 6 o’clock (Figures 4 to 6). The influence of school holidays in summer is recognizable during the year. Fewer accidents happen on weekends. Another time that fewer accidents happen is when the traffic operation is reduced during nights between 3 am and 5 am. The statistical basis for the temporal distribution of general accidents in road traffic in figures 4 and 5 are accidents with personal injury, accidents with serious property damage and accidents under the influence of alcohol.
Figure 4
Tram and road accidents during the year

Figure 5
Tram and road accidents during the week

Figure 6
Tram accidents during the day
To complete the overview over the accident occurrence, table 3 gives a comparison of absolute figures and other characteristics in accident occurrence between Dresden and other German cities (5). Looking at the absolute figures, the accident occurrence in Dresden seems to be highly serious, whereas the other characteristics of Dresden’s accident occurrence in tram traffic are close to average.

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<td>70,54</td>
<td>62,94</td>
<td>41,43</td>
</tr>
</tbody>
</table>

Abbreviations:
P    person accidents
C    collisions
AD   accident density in accidents per km
AL(IN) accident load in accidents per 1 000 inhabitants
AL(PA) accident load in accidents per 1 000 000 passengers
AR(Pkm) accident rate in accidents per 1 000 000 person km
AR(Vkm) accident rate in accidents per 1 000 000 vehicle km

Notes:
1) collisions and other
2) accidents
3) pedestrian accidents and other

Table 3
Characteristics of tram accidents in different cities in Germany

Track-Road Combinations with Increased Risk of Accidents

Within the Dresden tram network more than 70 accident black spots could be found (3). In this context intersections with at least five accidents are indicated as accident black spots (2). Up to 20 accidents were counted at a single intersection. Many intersections have been identified as accident black spots in subsequent years.
For some chosen accident black spots of the year 1995 sketches of accident circumstances have been worked out in (5). A thorough examination of these sketches has shown several driveway relationships between trams and vehicles, which very often contribute to the establishment of accident black spots. Figure 7 shows these typical track-road combinations.

- Case A often happens at separate tracks beside roads. Vehicles cross these tracks on priority junctions. Left-turning vehicles must wait for an adequate time gap in the priority stream. Therefore, the drivers focus their attention mainly on the vehicle traffic.

- Separate tracks beside roads play a major part in case B, too. However, in this case the separate track turns into a road-level track in the middle of the road, which vehicle drivers do not expect.

- Case C shows a road-level track in the middle of the road, which must be crossed by vehicles turning left. Vehicle drivers in the minor stream must pay attention not only to through trams but also on time gaps in priority streams.

- Cases D and E are characteristic for very wide cross sections, where trams go on separate tracks in the middle. The difference between cases D and E is the queueing space for at least one or two vehicles between the tram lines in case D.

- Cases F, G and H are likewise principally similar, while case F is possible everywhere along road-level tracks and cases G and H are only possible at fixed points in the street environment. These cases have in common that vehicle drivers are trying to move aside to the left. Because of this they get into the vehicle clearance envelope of trams that go on road-level tracks in the middle. According to the German road traffic laws, vehicles are not allowed to pass through tram stop areas at a high speed when passengers get on and off the tram.

- In case I only one lane is available to freely flowing vehicles between junctions. Queueing space for left-turning vehicles is separated from the through lane at the junction approach. However, getting in lane to the left in front of through trams is often a source of danger.

To sum this paragraph up it may be stated that an increased risk of accidents is caused by the transitions between separate or independent tracks to road-level tracks. On principle, the accident severity is expected to be especially high in cases A to E. At these track-road-combinations tram stream and vehicle stream hit one another at a relatively obtuse angle.
Figure 7
Track-road combinations with increased risk of accidents
Measures to Improve Safety in Tram Traffic

Suggestions to increase active and passive safety in tram traffic can be assigned to the fields of traffic engineering, passenger transportation and public relations. Measures in the field of traffic engineering refer at first to the traffic control in the roadside environment. It should be examined if turning prohibitions could reduce accident tolls significantly at priority junctions with high risk of accidents. As a result vehicle manoeuvres involving especially unfavourable visibility between tram and motor vehicle can be avoided. It is necessary to mark the vehicle clearance envelope of trams always clearly. This can be achieved through road markings or obvious changes in the pavement material. Incalculable crossing points of tracks with common conflict areas between tram and vehicle streams are to be equipped with traffic lights, if necessary. If tram stops are set in the middle of the road without separate tracks or tram stop islands, passengers cross the lanes of freely flowing vehicle streams. In this case, time islands signalized by traffic lights are recommended. This brings about a clear traffic control for both vehicle drivers and transferring passengers.

Measures in connection with passenger transportation first of all increase the passive safety of passengers in trams. As long as seats are vacant, as many passengers as possible should occupy them. This is especially true for elderly passengers and children. On the one hand, many passengers reject to take a seat on short trips. On the other hand, some passengers occupy two seats, although only one seat would be sufficient. Next to the doors especially marked seats should be reserved for handicapped passengers. Even if the tram is late, the tram drivers should bear in mind the necessity of safety for boarding and deboarding passengers. They should ensure moderate longitudinal and transverse acceleration (standing passengers).

In the field of public relations, the mutual consideration between vehicle drivers and tram traffic can be influenced. Short and informative announcements in local newspapers can be used to make vehicle drivers aware of the problems concerning tram traffic (5). For example, these announcements can be of the following or a similar wording:

<table>
<thead>
<tr>
<th>Your safety is important to us!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please pay attention to the tram traffic</td>
</tr>
<tr>
<td>at the junction Station Square.</td>
</tr>
<tr>
<td>This is an accident black spot.</td>
</tr>
<tr>
<td>We wish you a nice trip!</td>
</tr>
<tr>
<td>Your public transport company.</td>
</tr>
</tbody>
</table>

10
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SIMULATION OF INTERSECTION APPROACHES
WITH RANDOM AND UNIFORM ARRIVAL PATTERNS

Joseph C. Oppenlander and Jane E. Oppenlander

ABSTRACT

In simulation studies for signalized intersection approaches, various sensitivity analyses were
performed to discern the patterns among the parameters of arrival type, percentile queue length,
approach volume, and ratio of green time to cycle length (g/C). As a result, greater understanding
of the interactions between geometric and control features is provided for the design of intersection
approaches with protected movements. These interacting relationships are summarized in graphical
and tabular formats.

A simulation model was constructed to determine storage requirements on the approaches of
signalized intersections with separate-phase operation. Queue lengths were derived for 50th, 85th,
and 95th percentiles for through or turning movements that have no conflicting traffic. Design tables
were generated for practical ranges of lane volumes, cycle lengths, and green times.

In this work, random and uniform arrival patterns were simulated to account for differing vehicular
spacings. The random relationship models arrivals at isolated intersections, while a more uniform
pattern may exist in a signal system with a good level of coordination. As a result, these two arrival
models provide the likely range of vehicular spacing patterns on the approach to a signal
intersection.

A triangular distribution was developed from reported field data to describe the departure headways
by vehicle position in the queue. The simulated intersection was then operated in a stop-and-go
manner with selected cycle lengths and green times.

In the sensitivity analyses, conditions and/or relationships were developed for arrival patterns,
queuing conditions, and queue behavior. Finally, a design quick check provides an expedient
process to assess tradeoffs between lane volume and g/C ratio for storage requirements at the
selected percentile levels.
INTRODUCTION

In the design and operation of signalized intersections, relationships exist between geometric features and signal operations. In particular, storage requirements on intersection approaches are related to green times and cycle lengths in the signal-timing plans. Establishment of these relationships is essential for the traffic engineer who is involved in these tasks.

To relate these design and control parameters, the following simulation models were developed and evaluated for broad ranges of cycle length, green time, and approach volume by lane.

1. Protected movement with random arrivals.¹
2. Protected movement with uniform arrivals.²
3. Permitted left-turn movement with random arrivals.³

In the latter case, the opposing volume was included in the simulation process with a stop-and-go algorithm for the gap acceptance phase of the left-turn movement with the opposing traffic.

The purpose of this paper is to analyze various relationships among the parameters of arrival type, percentile queue length, approach volume, and ratio of green time to cycle length (g/C). As a result, greater understanding of the interactions between geometric and control features is provided for the design of approaches with protected movements at signalized intersections. Design relationships for exclusive left-turn lanes with permitted or protected/permittet operation are not included in this paper.

MODELS

The process of simulation is a valuable tool for the evaluation of both simple and complex traffic situations.⁴ With simple models, generic solutions to typical traffic events can be readily achieved for direct applications to design and control situations. When complex models are constructed, these results are valid only for a specific set of roadway-traffic parameters. As a result, no allowances are usually made for the normal variations in these variables throughout the day and the year.
The simulation in these studies was designed to model the interaction of vehicles arriving at the signalized intersection, of the signal operation, and of the movement of vehicles through the intersection. In the first work\(^1\), random vehicle arrivals were generated from a Poisson probability distribution. This situation models isolated intersections and street systems with little or no signal coordination. The model was then reconfigured in the second study\(^2\) to account for uniform-arrival patterns on the intersection approach. Travel on arterials and expressways with good signal progression is described with reasonably uniform arrivals at the intersections along the route.

In both studies, the movement of vehicles through the intersection is arranged on a first-in-first-out priority. If a vehicle arrives on a green indication, the unit is processed through the intersection. An arrival on a red indication is placed in the lane queue for response to the signal operation. When the green time is started, the departure rates are based on start-up headway values identified as Kell Field Data.\(^3\) These start-up times are specified as average, lower-limit, and upper-limit headways by position in the waiting queue. For each queue position, departure times were randomly generated from a triangular probability distribution defined by the three headway values.

Frequency distributions of queue lengths were prepared for each set of approach volumes, cycle lengths, and green times. Then, selected percentile storage requirements were tabulated in the format of design charts.

**RESULTS**

Simulations of the signalized intersection approach were performed for lane volumes from 50 to 800 vph in the intervals of 50 vph, for cycle lengths of 60, 75, 90, 105, 120, 150, and 180 sec, and for green times from 10 sec to two-thirds of the cycle length at spacings of 5 sec. These values were selected to provide design charts that are applicable to most signalized intersections. For each set of design variables, 1000 signal cycles were simulated to produce each queue-length distribution. This level of simulation provides a degree of precision that is within two to three percent for the calculated percentiles of storage requirements on an approach to a signalized intersection.
To provide reasonable ranges of values for intersection design, 50\textsuperscript{th}, 85\textsuperscript{th}, and 95\textsuperscript{th}-percentile queue lengths are summarized in tables by the seven selected cycle lengths. Tabulations were prepared for both the random\textsuperscript{1} and the uniform\textsuperscript{2} arrival models. These tables and their applications are discussed in the referenced publications.

Capacity analyses of signalized intersections are predicated on no blockage of any approach lanes.\textsuperscript{5} In design, care must be exercised to prevent any lane blocking by vehicles in adjacent lanes. In addition, the required clearance between the intersection and the nearest major driveway on the approach can be determined to reduce the potential for driveway by vehicles queued on the approach to the intersection. Thus, a complete knowledge of storage requirements is an integral part of good design for signalized intersections.

SENSITIVITY ANALYSES

The focus of this paper is on the interactions among the variables of arrival type (random or uniform), percentile queue length, approach volume, and ratio of green time to cycle length. The last parameter provides a measure, that is independent of green time and cycle length, in signal operation. The data for these sensitivity analyses are contained in the two sets of design tables for random and uniform arrivals with protected movements and no opposing volumes.\textsuperscript{1,2} The interacting relationships are summarized in tabular and/or graphical formats.

Although both sets of storage lengths were simulated primarily to develop guidelines for intersection design, various characteristics of the design variables were appraised to determine any significant trends. The scope of these analyses includes influences of arrival patterns on storage requirements, approach volumes at which queues become unstable, and behavior of queues on approaches to signalized intersections.
Arrival Patterns

Several comparisons between the corresponding storage lengths for random and uniform arrivals should be noted in the application to design situations. As a rule for all three percentile values, shorter storage requirements exist for uniform than for random arrivals. However, some convergence is apparent with increasing green times and/or with increasing lane volumes. Unstable queues (infinite length), on the other hand, occur at the same volume level for each effective green time regardless of the arrival pattern.

In many situations, negligible change in storage distance occurs in the percentiles for a specific set of parameters with uniform arrivals. These values in the random distributions are more variable in the percentile categories. In Figure 1, relative frequency distributions of random and uniform arrivals are shown for a typical situation with a lane volume of 450 vph, a cycle length of 75 sec, and a green time of 40 sec. This difference for the two arrival patterns is explained by greater variability in the resulting storage-length distributions for random as compared to uniform arrivals. As a result, more efficient traffic flows and reduced storage distances occur when nearly uniform arrivals are established by signal progression.

For random arrivals, 50th-percentile queue lengths are approximated by the product of lane volume in vehicles per second and red time in seconds. The respective values for 85th- and 95th-percentile lengths are determined by increasing the product with multipliers of 1.5 and 2.0. For the most part, this work substantiates these somewhat heuristic relationships. However, this method is not valid for uniform arrivals on the approach lanes. Care must be exercised in the use of these approximations. As compared to the results of simulation, the estimated storage requirements are well underestimated for values of about 0.075 or less in the ratio of green time in seconds to lane volume in vehicles per hour. This limiting ratio is fairly independent of cycle length.

The intersection designer now has a choice between two arrival categories in the trade-off selection among cycle length, effective green time, and lane storage distance. If the arrival characteristics on
any approach lane are deemed to represent some pattern that is between these two limiting conditions, then interpolation is feasible to approximate more closely the actual traffic situation.

Unstable Queues

The approach volumes at which the storage distance becomes unstable are recorded by the g/C ratio in Table 1. These values, to the nearest 50 vph, are equal for both random and uniform arrivals. A linear relationship, that nearly passes through the origin, exists for these volumes as a function of the g/C ratio. The slope of this line is 1500 vph per sec/sec. Therefore, the volume level for unstable lane operation is incremented by 150 vph for each increase of 0.1 sec/sec in the g/C ratio. The limiting lane volume in passenger cars per hour, as queue lengths increase, is equal to 1500 times the ratio of green time to cycle length in seconds per second.

Figure 1 - Frequency Distributions
Random vs. Uniform Arrivals

![Figure 1 - Frequency Distributions](image_url)
Queue Behavior

Selected graphs of storage lengths by lane volumes and arrival types are presented as Figures 2, 3, and 4, respectively, for 50th-, 85th-, and 95th-percentile storage distances. These plots represent the relationship for g/C = 0.50 at cycle lengths of 60, 120, and 180 sec. In general, these relationships are positive exponential functions that approach infinity at the levels stated in Table 1. The initial portions of these plots closely resemble linear conditions. The roughness of these plots results from the ‘rounding up’ of the storage lengths measured in vehicle units. As evident in these graphs, queuing distance increases with greater cycle length. Thus storage requirements are extended because fewer signal cycles occur in a given time period for longer cycle durations. Although four additional cycle lengths were included in the two simulation studies, these relationships can be readily interpolated in Figures 2 through 4 for either random or uniform arrivals. Similar patterns exist for other plots of percentile queue length versus approach volume with different g/C ratios.

<table>
<thead>
<tr>
<th>g/C Ratio</th>
<th>Percent</th>
<th>Approach Volumes, vph*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Random Arrival</td>
</tr>
<tr>
<td>1/6</td>
<td>16.7</td>
<td>250</td>
</tr>
<tr>
<td>1/5</td>
<td>20.0</td>
<td>300</td>
</tr>
<tr>
<td>1/4</td>
<td>25.0</td>
<td>400</td>
</tr>
<tr>
<td>1/3</td>
<td>33.3</td>
<td>500</td>
</tr>
<tr>
<td>1/2</td>
<td>50.0</td>
<td>750</td>
</tr>
<tr>
<td>3/5</td>
<td>60.0</td>
<td>900</td>
</tr>
<tr>
<td>2/3</td>
<td>66.7</td>
<td>1000</td>
</tr>
<tr>
<td>4/5</td>
<td>80.0</td>
<td>1200</td>
</tr>
</tbody>
</table>

* nearest 50 vph
As practical design guidelines, maximum queue lengths of five and ten vehicle units have been delimited by the horizontal lines on Figures 2 through 4. The value of 5 vehicle units, or 125 ft/40m, may be reasonable for a special turn lane. For ten vehicle units, or 250 ft/75m, this storage requirement appears acceptable for an approach lane with through or through/right-turn movements. Designs with stipulated lane volumes are not acceptable when the combination of cycle length and arrival type is above the horizontal line for the selected maximum queue length. While the 85th- and/or 95th-percentile queue lengths are proper for design situations, storage requirements at the 50th-percentile level may serve as 'tolerable standards' to assess the adequacy of existing intersection approaches.

**DESIGN QUICK CHECK**

From the type of relationships presented in Figures 2 through 4, allowable approach volume by lane for five and ten vehicle units are summarized as design quick check values in Table 2. This information permits a rapid assessment of trade-offs between lane volume and g/C ratio for the selected queue limits at the three categories of 50th, 85th, and 95th percentiles. Only plots of queue length versus approach volume for a g/C of 0.50 are contained in this paper.

The g/C ratios in Table 2 represent typical allocations of effective green times at signalized intersections. Because increasing percentile storage requirements necessitate greater probabilities for successful designs, these lengths correspond to decreasing approach volumes. The quick design values do not depend on cycle length (60 to 180 sec) and arrival type (random or uniform). However, more exact storage requirements in vehicle units are found in the appropriate tables noted in References 1 and 2.

Linear regression equations were established between lane volume and g/C ratio for each category of queue percentile and storage length in Table 2. The corresponding intercepts and slopes are presented in the portion of the table with the g/C ratio as the independent variable. High positive linear relationships are evident in the correlation coefficients (r) that range from 0.95 to 0.99. These values are given in the last row of Table 2. For example, the limiting volume of 275 vph exists for
a g/C of 0.43 and a storage distance of ten vehicle units at the 85th percentile. If this value is not acceptable, then other g/C ratios can be tried until a proper design is achieved or the design parameters are changed.

### TABLE 2
DESIGN QUICK CHECK

<table>
<thead>
<tr>
<th>g/C</th>
<th>50th-Percentile Queue**</th>
<th>85th-Percentile Queue***</th>
<th>95th-Percentile Queue***</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 veh units</td>
<td>10 veh units</td>
<td>5 veh units</td>
</tr>
<tr>
<td>0.20</td>
<td>125</td>
<td>250</td>
<td>75</td>
</tr>
<tr>
<td>0.33</td>
<td>150</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>0.40</td>
<td>175</td>
<td>350</td>
<td>100</td>
</tr>
<tr>
<td>0.50</td>
<td>200</td>
<td>400</td>
<td>125</td>
</tr>
<tr>
<td>0.67</td>
<td>300</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td>Int.</td>
<td>34.8</td>
<td>69.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Slope</td>
<td>369.6</td>
<td>739.3</td>
<td>258.3</td>
</tr>
<tr>
<td>r</td>
<td>0.97</td>
<td>0.97</td>
<td>0.95</td>
</tr>
</tbody>
</table>

* Nearest 25 vph
** Tolerable level
*** Design level
SUMMARY

Storage requirements for approach lanes at signalized intersections were modeled by simulation for the arrival of vehicles at random and uniform rates. Design charts were prepared to include a broad range of lane volumes, cycle lengths, and green times.\textsuperscript{1,2}

The storage distances are applicable for any movement for which no opposing vehicles are involved. In design, care must be taken to avoid any potential blockage of through and special-turn lanes by traffic volumes in adjacent lanes. Also, the needed clearance between the intersection and the nearest major driveway on the approach can be determined to minimize the potential for driveway blockage by queued vehicles on the intersection approach. However, these design values for both random and uniform arrivals are not valid for special-turn lanes with no separate-phase control that permit conflicting traffic movements.

Various relationships were determined in the sensitivity analyses. Although storage requirements are generally greater for random than for uniform arrivals, convergence takes place with increasing green times and/or lane volumes. In addition, queue lengths become unstable at equal volume levels for the two arrival patterns. Graphs of queue length versus approach volume evidence positive exponential behavior with reasonable linearity until the lane volume approaches the limit for stable queues.

Although good progression along a major roadway may produce uniform spacings between vehicles, breakdowns in coordination may produce random arrivals at the signalized intersections. These circumstances could result from any combination of controller malfunctions and internal/marginal frictions for the traffic streams. Therefore, conservative design results with the use of the storage-length tables for random arrivals.

Design trade-offs among storage length, cycle length, and green time are readily achieved with the tabulated values for the two arrival conditions. This design process results in an optimal balance
among intersectional approaches through the determination of acceptable geometric and control elements at a signalized intersection with separate phase control.

COMPLETE SET OF TABLES

Complete sets of the design tables for the three studies listed in the Introduction may be obtained from Gail Currier, The University of Vermont, Department of Civil & Environmental Engineering, 213 Votey Hall, Burlington, VT 05405-0156; fax 802-656-8446; email: currier@emba.uvm.edu
REFERENCES


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CRASH REDUCTIONS FOLLOWING INSTALLATION
OF ROUNDBOOUTS IN THE UNITED STATES

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ABSTRACT
Modern roundabouts are designed to control traffic flow at intersections without the use of stop signs or traffic signals. U.S. experience with modern roundabouts is rather limited to date, but in recent years there has been growing interest in their potential benefits and a relatively large increase in roundabout construction. The present study evaluated changes in motor vehicle crashes following conversion of 24 intersections from stop sign and traffic signal control to modern roundabouts. The settings, located in 8 states, were a mix of urban, suburban, and rural environments. A before-after study was conducted using the empirical Bayes approach, which accounts for regression to the mean. Overall, the empirical Bayes procedure estimated highly significant reductions of 38 percent for all crash severities combined and 76 percent for all injury crashes. Reductions in the numbers of fatal and incapacitating injury crashes were estimated to be about 90 percent. Overall, results are consistent with numerous international studies and suggest that roundabout installation should be strongly promoted as an effective safety treatment for intersections in the U.S.
INTRODUCTION

The modern roundabout is a form of intersection traffic control that has become increasingly common around the world but is seldom used in the United States. Circular intersections are not a new idea and, in fact, predate the advent of the automobile. The first one-way rotary system for motor vehicle traffic in the United States was put into operation in 1905 at Columbus Circle in New York City (1).

The main difference between modern roundabouts and older circles/rotaries is the design speed. Older rotaries typically were built according to 1940s-era design standards or even older guidelines, which generally were intended for vehicle speeds of 25 mph or more. Drivers typically enter older traffic circles at speeds of 35 mph or more. In contrast, modern roundabouts are designed for very low traffic speeds, about 15 mph. The low design speed is accomplished through two primary design features: drivers must enter the roundabout facing a central island rather than tangentially (this feature is known as deflection), and the approaches to the roundabout are curved to promote low entry speeds. Common characteristics that define a modern roundabout and provide safety features are: drivers entering a roundabout must yield to vehicles within the circulatory roadway, keeping weaving to a minimum; roundabout entrances and exits are curved to promote low traffic speeds; traffic circulates counterclockwise, passing to the right of a central island; raised “splitter” islands dividing the roadway at entrances and exits provide refuge for pedestrians, ensure drivers travel in the intended path, and separate opposing traffic (Figure 1). In addition, pedestrian activities are prohibited on the central island, pedestrians are not intended to cross the circulatory roadway, and when pedestrian crossings are provided for approach roads they are placed approximately one car length back from the entry point.

Numerous studies, mostly in the international literature, indicate that modern roundabouts are safer than other methods of intersection traffic control, and that converting intersections from stop signs or traffic signals to roundabouts is associated with substantial reductions in motor vehicle crashes and injuries. For example, Schoon and van Minnen (2) studied 181 Dutch intersections converted from conventional controls (traffic signals or stop signs) to modern roundabouts and reported that crashes and injuries were reduced by 47 and 71 percent, respectively; the more severe injury crashes (resulting in hospital admissions) were reduced by 81 percent. Troutbeck (3) reported a 74 percent reduction in the rate of injury crashes following conversion of 73 roundabouts in Victoria, Australia. These and similar studies may overestimate the magnitude of crash reductions associated with conversion of intersections to roundabouts by failing to control for regression-to-the-mean effects — a major problem affecting the validity of many road safety improvement studies. A thorough review of the literature was conducted by Elvik et al. (4), who concluded that converting from yield, two-way stop, or traffic signal control to a roundabout reduces the total number of injury crashes by 30-40 percent. Reductions in the number of pedestrian crashes were in the same range. Bicycle crashes were reduced by approximately 10-20 percent. It should be noted that the Elvik et al. study was a meta-analysis that included some circular intersections not meeting the typical definition of modern roundabouts. Regression to the mean was not controlled for.

U.S. experience with modern roundabouts is rather limited to date, but there has been growing interest in their potential benefits and, recently, a relatively large increase in roundabout construction. Garder (5) conducted an extensive review of existing and planned U.S. installations and reported strong activity in several states including Colorado, Florida, Maine, Maryland, Michigan, Nevada, Vermont, and Washington. A recent, but limited before-after crash study was conducted by Flannery and Elefteriadou (6) based on 8 roundabouts, 3 in Florida and 5 in Maryland. Results were promising, suggesting consistent reductions in crashes and injuries, but the analyses were limited in scope.
The present before-after study was designed to better estimate the nature and magnitude of crash reductions following installation of modern roundabouts in the United States. It included a greater number of intersections and employed more powerful statistical analysis tools than the simple before-after comparisons used in prior studies.

**METHOD**

The empirical Bayes approach was employed to properly account for regression to the mean while normalizing for differences in traffic volume between the before and after periods. The change in safety at a converted intersection for a given crash type is given by:

\[ B - A, \]  

(1)
where $B$ is the expected number of crashes that would have occurred in the after period without the conversion and $A$ is the number of reported crashes in the after period.

To eliminate regression-to-the-mean effects and to reduce uncertainty in the results, $B$ was, in general, estimated using an empirical Bayes procedure (7) described more fully in the appendix. In essence, a regression model is used to first estimate the annual number of crashes ($P$) that would be expected at intersections with traffic volumes and other characteristics similar to the one being analyzed. The regression estimate is then combined with the count of crashes ($x$) in the $n$ years before conversion to obtain an estimate of the expected annual number of crashes ($m$) at the intersection before conversion. This estimate of $m$ is:

$$m = w_1(x) + w_2(P),$$

where the weights $w_1$ and $w_2$ are estimated from the mean and variance of the regression estimate as:

$$w_1 = P/(k + nP) \quad (3)$$

$$w_2 = k/(k + nP), \quad (4)$$

where

$$k = P^2/\text{Var}(P) \quad (5)$$

is a constant for a given model and is estimated from the regression calibration process.

Factors then are applied to account for the length of the after period and differences in traffic volumes between the before and after periods. The result is an estimate of $B$. The procedure also produces an estimate of the variance of $B$. The significance of the difference ($B-A$) is established from this estimate of the variance of $B$ and assuming, based on a Poisson distribution of counts, that:

$$\text{Var}(A) = A. \quad (6)$$

Uncertainty in the estimates of safety effects also can be described with the use of likelihood functions, which have been presented in the full project report (8).

**ASSEMBLY OF DATA AND REGRESSION MODELS**

**Data for Converted Intersections**

The analyses were confined to 8 states — California, Colorado, Florida, Kansas, Maine, Maryland, South Carolina, and Vermont — where a total of 24 intersections were converted to modern roundabouts between 1992 and 1997. There are a few modern roundabouts in the United States that are not included in the present analysis because data were not available or the roundabouts were too new. Of the 24 intersections studied, 20 were previously controlled by stop signs, and 4 were controlled by traffic signals.

Fifteen of the roundabouts were single-lane circulation designs, and 9, all in Colorado, were multilane.

Summary data for the study intersections are given in Table 1. For each intersection, crash data were obtained for periods before and after conversion. The construction period, as well as the first month after completion, were excluded from analysis. The lengths of the before and after periods varied in accordance with available crash data. In no case was a period shorter than 15 months. Data were extracted from printed police crash reports and, where not available, from report summaries. Information regarding injuries also was derived from police crash reports. Police reports convey the detection and apparent severity of injuries, either through the so-called KABCO scale (Killed, A injury, B injury, C injury, Only property damage) or by separating injuries into three categories: possible injury, non-incapacitating injury, and the more severe incapacitating injuries. In this study, “possible” injuries were not counted as injuries. Injury data based on police reports have known limitations, especially in regard to injury...
Regression Models

From data about intersections not converted and a consideration of existing models, the regression models required for the empirical Bayes estimates of safety effect (Equations 2-5) were assembled. New models were calibrated for stop controlled urban intersections, whereas other models were adopted from Lord (9) for signalized intersections and Bonneson and McCoy (10) for rural stop controlled intersections. For urban stop controlled intersections, two levels of models were calibrated:

$$ \text{crashes/year} = (\alpha) (\text{total entering AADT})^\beta $$  \hspace{1cm} (7)

$$ \text{crashes/year} = (\alpha) (\text{total entering AADT})^{\beta_1} (\text{minor road proportion of AADT})^{\beta_2} $$ \hspace{1cm} (8)

Two levels of models were required because in a few instances, estimates of annual average daily traffic (AADT) were available only for the intersection as a whole. In most cases, entering AADTs were available for each approach, and level 2 models, which produce better estimates, could be applied. The data set used for the calibration was from a sample of urban intersections in Florida, Maryland, and Toronto, Ontario. These data confirmed the stability of crash reporting over the time period of the conversion data in two states that accounted for 9 of the 24 intersections. The models adopted from previous research were of the same forms as Equations 7-8.

Severity. During the study period, there were no known changes in reporting practices that would cause a change in the number of reported crashes.
Following recent works by Persaud et al. (11) and Bonneson and McCoy (10), the Generalized Linear Interactive Modelling (GLIM) software package (12) was used for estimating the parameters $\alpha$ (actually $\ln(\alpha)$ since a linear model is fitted) and the $\beta$s for Equations 7-8 for all crashes combined and for injury crashes only. GLIM allows the specification of a negative binomial distribution, which now is regarded as being more appropriate to describe the count of crashes in a population of entities than the Poisson or normal distributions assumed in conventional regression modelling. In specifying a negative binomial error structure, the parameter $k$ (Equation 5), which relates the mean and variance, had to be iteratively estimated from the model and the data as part of the calibration process.

Typical model calibration results are illustrated in Table 2, which shows the level 2 coefficient estimates for four-legged, one-street stopped intersections. Models were also estimated for three-legged stop controlled intersections. Full details of both the new and existing models are given in the project report (8).

**TABLE 2** Level 2 Reference Population Models for One Street Stopped, Four-Legged Urban Intersections Considering Distribution of AADT Between Major and Minor Road, crashes/year = $\alpha \beta_1 \beta_2$ (total entering AADT)($\beta_1$ (minor road proportion of AADT))^2

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Jurisdiction</th>
<th>$\ln(\alpha)$ (Standard Error)</th>
<th>$\beta_1$ (Standard Error)</th>
<th>$\beta_2$ (Standard Error)</th>
<th>$k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All combined</td>
<td>Maryland</td>
<td>$-9.900 (2.04)$</td>
<td>$1.198 (0.210)$</td>
<td>$0.370 (0.125)$</td>
<td>3.10</td>
</tr>
<tr>
<td></td>
<td>Florida</td>
<td>$-9.868 (2.07)$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td>$-9.886 (2.01)$</td>
<td>$1.202 (0.213)$</td>
<td>$0.376 (0.107)$</td>
<td>3.10</td>
</tr>
<tr>
<td>Injury</td>
<td>Maryland</td>
<td>$-8.271 (2.33)$</td>
<td>$0.861 (0.249)$</td>
<td>$0.173 (0.127)$</td>
<td>3.34</td>
</tr>
<tr>
<td></td>
<td>Florida</td>
<td>$-8.015 (2.37)$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RESULTS**

Table 3 summarizes the estimated crash reductions and provides two measures of safety effects. The first is “index of safety effectiveness” ($\theta$), which is approximately equal to the ratio of the number of crashes occurring after conversion to the number expected had conversion not taken place. The second is the more conventional percent reduction in crashes, which is equal to $100(1-\theta)$. Overall, the empirical Bayes procedure estimated a highly significant 38 percent reduction for all crash severities combined for the 24 converted intersections. Because injury data were not available for the period before construction of the 4 roundabouts in Vail, overall estimates for changes in injury crashes are based on the other 20 intersections. The empirical Bayes procedure estimated a highly significant 76 percent reduction for injury crashes for these 20 converted intersections. These estimates are slightly lower than those that were obtained using a simple before and after comparison instead of the empirical Bayes procedure.

Because of major operational differences between various roundabout designs and settings, results were analyzed and reported for several groups of conversions for which there were sufficient crash data to provide meaningful results. These include 9 urban single-lane roundabouts that prior to construction were stop controlled, 5 rural single-lane roundabouts that prior to construction were stop controlled, 7 urban multilane roundabouts that prior to construction were stop controlled, and 3 urban intersections converted to roundabouts from traffic signal control. For the group of 9 urban single-lane roundabouts converted from stop control, the empirical Bayes procedure estimated a highly significant 61 percent reduction for all crash severities combined and a 77 percent reduction for injury crashes. For the group of 5 rural single-lane roundabouts converted from stop control, similar effects were estimated — a 58 percent reduction for all crash severities combined and an 82 percent for injury...
crashes. For the group of 6 urban multilane roundabouts, however, the estimated effect on all crash severities combined was smaller — a 5 percent reduction. Because injury data were not available for the period before construction of 4 of these roundabouts, overall estimates for changes in injury crashes were not computed for this group of intersections. For the 4 roundabouts converted from traffic signal control, estimated reductions were 35 percent for all crash severities combined and 74 percent for injury crashes. Three of these roundabouts had multilane circulation designs.

For completeness, partial results also are given for individual conversions in a group. Readers are cautioned about drawing conclusions from these results because there is a significant likelihood that the change in safety for individual conversions is due to chance. In some cases, however, there may be logical explanations for an apparent deterioration in safety following roundabout conversion. At the Gainesville site, for example, transportation officials were unable to secure adequate right of way to construct a roundabout to design specifications that would accomplish the desired deflection and speed reduction. This may explain the apparent absence of crash reduction at this site. Another example is the Santa Barbara site, which was the only one that was all-way stopped controlled before conversion. In the light of evidence that all-way stop control is already a safety

<table>
<thead>
<tr>
<th>Group Characteristic Before Conversion/Jurisdiction</th>
<th>Count of Crashes</th>
<th>Crashes Expected During Period After Conversion</th>
<th>Index of Effectiveness Without Conversion</th>
<th>Percent Reduction in Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Lane, Urban, Stop Controlled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bradenton Beach, FL</td>
<td>1</td>
<td>9.9 (3.6)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Fort Walton Beach, FL</td>
<td>4</td>
<td>16.9 (3.9)</td>
<td>2.7 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Gorham, ME</td>
<td>4</td>
<td>6.8 (1.4)</td>
<td>0.9 (0.4)</td>
<td></td>
</tr>
<tr>
<td>Hilton Head, SC</td>
<td>9</td>
<td>42.8 (6.0)</td>
<td>8.2 (1.9)</td>
<td></td>
</tr>
<tr>
<td>Manchester, VT</td>
<td>1</td>
<td>1.7 (0.7)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Manhattan, KS</td>
<td>0</td>
<td>4.2 (1.2)</td>
<td>1.2 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Montpelier, VT</td>
<td>1</td>
<td>4.3 (1.8)</td>
<td>1.1 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Santa Barbara, CA</td>
<td>17</td>
<td>17.97 (4.9)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>West Boca Raton, FL</td>
<td>7</td>
<td>8.1 (3.0)</td>
<td>2.6 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Entire group (9)</td>
<td>44</td>
<td>112.6 (10.2)</td>
<td>16.6 (2.6)</td>
<td>0.39 (0.07) 0.23 (0.12) 61 77</td>
</tr>
<tr>
<td>Single Lane, Rural, Stop Controlled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anne Arundel County, MD</td>
<td>14</td>
<td>24.6 (4.0)</td>
<td>6.2 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Carroll County, MD</td>
<td>4</td>
<td>15.2 (2.6)</td>
<td>3.2 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Cecil County, MD</td>
<td>10</td>
<td>14.3 (2.9)</td>
<td>5.6 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Howard County, MD</td>
<td>14</td>
<td>36.7 (5.5)</td>
<td>7.7 (2.1)</td>
<td></td>
</tr>
<tr>
<td>Washington County, MD</td>
<td>2</td>
<td>14.4 (3.1)</td>
<td>4.2 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Entire group (5)</td>
<td>44</td>
<td>105.2 (8.4)</td>
<td>26.9 (3.4)</td>
<td>0.42 (0.07) 0.18 (0.09) 58 82</td>
</tr>
<tr>
<td>Multilane, Urban, Stop Controlled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avon, CO</td>
<td>3</td>
<td>19.9 (4.9)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Avon, CO</td>
<td>17</td>
<td>12.2 (3.1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Vail, CO</td>
<td>14</td>
<td>19.1 (4.4)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Vail, CO</td>
<td>61</td>
<td>50.9 (7.6)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Vail, CO</td>
<td>8</td>
<td>9.8 (2.1)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Vail, CO</td>
<td>15</td>
<td>11.8 (2.3)</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Entire group (6)</td>
<td>118</td>
<td>123.7 (11.0)</td>
<td>n/a</td>
<td>0.95 (0.10) n/a 5 n/a</td>
</tr>
<tr>
<td>Urban, Signalized</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avon, CO</td>
<td>44</td>
<td>49.8 (7.0)</td>
<td>5.4 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Avon, CO</td>
<td>13</td>
<td>30.1 (5.7)</td>
<td>2.3 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Avon, CO</td>
<td>18</td>
<td>52.1 (7.0)</td>
<td>5.3 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Gainesville, FL</td>
<td>11</td>
<td>4.8 (1.5)</td>
<td>1.3 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Entire group (4)</td>
<td>86</td>
<td>131.7 (10.9)</td>
<td>15.0 (2.7)</td>
<td>0.65 (0.09) 0.26 (0.14) 35 74</td>
</tr>
<tr>
<td>All conversions (24)</td>
<td>292</td>
<td>472.6 (20.4)</td>
<td>58.5 (5.1)</td>
<td>0.62 (0.04) 0.24 (0.07) 38 76</td>
</tr>
</tbody>
</table>

— Data not available
improvement over one-street stopped control, it should not be surprising that there would be little or no marginal safety benefit of further conversion to a roundabout.

Effects on fatal crashes and those causing incapacitating injuries are more difficult to measure due to the small samples, but indications are that such crashes were substantially reduced. For the 20 converted intersections with injury data, there were 3 fatal crashes during the before period and none during the after period. The fatal crashes may have contributed to the fact that the roundabouts were constructed and may therefore contribute to the regression-to-the-mean phenomenon. There were 27 incapacitating injury crashes during the before period and only 3 during the after period. Taking into account the durations of the before and after periods and increases in traffic volume, and adjusting for regression to the mean (estimated to be roughly 22 percent), the observed value of 3 incapacitating or fatal injury crashes during the after period is substantially and significantly less than the 26.6 expected. The estimated reduction in fatal and incapacitating injury crashes is 89 percent (p<0.001).

There were 4 reported pedestrian crashes during the before period and 1 (with minimal injuries) during the after period. Four bicyclists were injured during the before period and 3 during the after period. However, these samples are too small to give conclusive evidence on the safety of these road-user groups at roundabouts.

DISCUSSION

Results of this study indicate that converting conventional intersections from stop sign or traffic signal control to modern roundabouts can produce substantial reductions in motor vehicle crashes. Of particular note are the large reductions found in the number of injury crashes, especially those involving incapacitating and fatal injuries. These findings generally are consistent with results of numerous international studies. The accumulated knowledge suggests that roundabout construction should be strongly promoted as an effective safety treatment for intersections. Given the large numbers of injury (700,000) and property damage (1.3 million) crashes that occur each year at traffic signals and stop signs in the United States (13), widespread construction of roundabouts can produce substantial reductions in injuries and property damage losses associated with motor vehicle use on public roads.

It is possible that the smaller safety effect observed for the group of urban intersections that previously were multilane and stop controlled may be due to differences in safety performance of single-versus multilane roundabout designs. However, a firm conclusion cannot be made because of other important differences between conversions in Colorado and those in other states. For example, the 2 Avon roundabouts that previously were multilane and stop controlled are part of freeway interchanges that also include nearby intersections that were previously four-way stop controlled. The multilane roundabouts do seem to be effective in eliminating most incapacitating injury crashes.

Crash reductions resulting from conversion of conventional intersections to modern roundabouts can be attributed primarily to two factors: reduced traffic speeds and elimination of specific types of motor vehicle conflicts that frequently occur at angular intersections. These conflicts include left turns against opposing/oncoming traffic, front-to-rear conflicts (often involving the lead vehicle stopping or preparing to stop for a traffic signal or stop sign), and right-angle conflicts at traffic signals and stop signs. Retting et al. (14) reported that crashes associated with these three intersection traffic conflicts account for two-thirds of police-reported crashes on urban arterials. Red light running crashes, which involve side impacts at relatively high speeds, are especially injury producing (15); such impacts are virtually non-existent at roundabouts.
Although the sample was too small to estimate effects on pedestrian crashes, Scandinavian evaluations of roundabouts conclude that single-lane roundabouts are very safe for pedestrians (16). Data from this study give no reason to doubt that those experiences can be translated to North America. And none of the multilane roundabouts have had a single pedestrian crash so far, even though there were two crashes during the before period at these sites. Likewise, Scandinavian experience shows that single-lane roundabouts with one-lane entries are very safe for bicyclists.

Some have expressed concern that older drivers may have difficulties adjusting to roundabouts. However, in this study, the average age of crash-involved drivers did not increase following the installation of roundabouts, suggesting that roundabouts do not pose a problem for older drivers.

In addition to reducing the risk of motor vehicle crashes and injuries, conversion to roundabouts can produce other important societal benefits including reductions in vehicle emissions, noise, fuel consumption, and traffic delays (17,18). Roundabouts also can improve the aesthetic appearance of intersections by providing opportunities for landscaping and architectural treatments. Roundabouts in place of traffic signals can provide cost savings for local governments by avoiding the expense of new traffic signal construction and maintenance.

Roundabouts are not feasible, nor appropriate, at all intersections. Sufficient right of way must be available for construction of the circular intersection. Typically, a modern roundabout has an outer diameter of approximately 100 feet (30 m). This allows for large enough deflections to reduce speeds to an appropriate level. However, land can be saved compared with signalization because approach roads can be kept narrower. Capacity constraints and limited rights of way eliminate from consideration many busy urban intersections, especially those located in central business districts. Also, intersections with high volumes of both bicycle and motor vehicle traffic may not be good candidates for roundabouts. There remains a need to develop a procedure for estimating the likely safety consequences of a contemplated installation. In the meantime, it is suggested that future installations be patterned after the ones found in this study to have had a very positive safety experience.

ACKNOWLEDGEMENTS
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REFERENCES


APPENDIX — EMPIRICAL BAYES ESTIMATION

The theory is covered in detail elsewhere (Hauer, 1997), so what is presented here is merely an illustration. Consider the Anne Arundel County, Maryland, intersection converted in 1994 for which the crash counts and AADTs on the approaches were as follows.

<table>
<thead>
<tr>
<th>Months (years) of crash data</th>
<th>Before Conversion</th>
<th>After Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count of total crashes</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>Major approaches AADT</td>
<td>10,654</td>
<td>11,956</td>
</tr>
<tr>
<td>Minor approaches AADT</td>
<td>4,691</td>
<td>5,264</td>
</tr>
</tbody>
</table>

### Estimating B: The Crashes That Would Have Occurred in the After Period without the Conversion

First, using the model from Bonneson and McCoy (1993), the regression estimate ($Y$) of the number of total crashes/year during the before period is:

$$P(\text{crashes/year}) = 0.000379 \times (\text{major road AADT})^{0.256} \times (\text{minor road AADT})^{0.831}$$

$$= 0.000379 \times (10,654)^{0.256} \times (4,691)^{0.831} = 4.58.$$  

Then, the expected annual number of crashes during the before period is estimated as:

$$m_b = \frac{k + x_b}{(k/P + y_b)},$$

where $x_b$ is the count of crashes during the before period of length $y_b$ years and $k = 4.0$ is a parameter estimated in the regression model. Thus, the expected annual number of crashes during the before period is:

$$m_b = \frac{4.0 + 34}{(4/4.58) + 4.67} = 6.860.$$  

To estimate $B$, the length of the after period and differences in the AADTs between the before and after period must be considered. This is accomplished by first multiplying the expected annual number of crashes in the before period by $R$, the ratio of the annual regression predictions for the after and before periods. In the after period:

$$P(\text{crashes/year}) = 0.000379 \times (11,956)^{0.256} \times (5,264)^{0.831} = 5.19.$$  

The ratio $R$ of the after period to the before period regression predictions is:

$$R = \frac{5.19}{4.58} = 1.133,$$

which gives:

$$m_a = R \times m_b = 1.133 \times 6.860 = 7.772 \text{ crashes/year}.$$  

Finally, to the estimate of $B$, the number of crashes that would have occurred in the after period had the conversion not taken place, $m_a$ is multiplied by $y_a$, the length of the after period in years. Thus:

$$B = 7.772 \times 3.17 = 24.61.$$  

Recall that 14 crashes actually occurred. The variance of $B$ is given by:

$$Var(B) = B \times R \times y_a / (P + y_b) = 24.61 \times 1.133 \times 3.17 / (0.873 + 4.333) = 16.93.$$  

### Estimation of Safety Effect

In the estimation of changes in crashes, the estimate of $B$ is summed over all intersections in the converted group and compared with the count of crashes during the after period in that group (Hauer 1997). For the 5 conversions in Maryland, the table below gives the estimates of $B$, variance of these estimates, and the count of crashes in the after period.

<table>
<thead>
<tr>
<th>Count (A)</th>
<th>Empirical Bayes Estimate ($B$)</th>
<th>Var($B$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>36.71</td>
<td>30.63</td>
</tr>
<tr>
<td>14</td>
<td>24.62</td>
<td>15.95</td>
</tr>
<tr>
<td>2</td>
<td>14.38</td>
<td>9.40</td>
</tr>
<tr>
<td>10</td>
<td>14.33</td>
<td>8.55</td>
</tr>
<tr>
<td>4</td>
<td>15.16</td>
<td>6.76</td>
</tr>
</tbody>
</table>

Sum $\lambda = 44$ Sum $\pi = 105.19$ Sum $\lambda = 71.29$

The variance of $B$ is summed over all conversions. The variance of the after period counts, $A$, assuming that these are Poisson distributed, is equal to the sum of the counts. There are two ways to estimate safety effect as shown below. For each, the estimation of the variance is illustrated.
**Method 1: Reduction in Expected Number of Crashes ($\delta$)**

This is the difference between the sums of the $B$s and $A$s over all sites in a conversion group. Let:

\[
\pi = \sum B \\
\lambda = \sum A;
\]

thus:

\[
\delta = \pi - \lambda.
\]

For the Maryland conversion data in the table above:

\[
\delta = 105.19 - 44 = 61.19.
\]

The variance of $\delta$ is given by:

\[
Var(\delta) = \sum Var(B) + \sum Var(A).
\]

For the Maryland conversion data in the table above:

\[
Var(\delta) = 71.29 + 44 = 115.29.
\]

**Method 2: Index of Effectiveness ($\theta$)**

A biased estimate of $\theta$ is given by:

\[
\theta = \frac{\lambda}{\pi}.
\]

The percent change in crashes is in fact $100(1-\theta)$; thus a value of $\theta = 0.7$ indicates a 30 percent reduction in crashes.

From Hauer (1997), an approximate unbiased estimate of $\theta$ is given by:

\[
\theta = \frac{\theta}{\lambda} \left\{ 1 + \frac{Var(\pi)}{\pi^2} \right\}.
\]

For the Maryland conversion data in the table above:

\[
\theta = \frac{44/105.19}{1 + (71.29/105.19^2)} = 0.416.
\]

The variance of $\theta$ is given by:

\[
Var(\theta) = \theta^2 \left[ \frac{Var(\lambda)}{\lambda^2} + \frac{Var(\pi)}{\pi^2} \right] / \left[ 1 + \frac{Var(\pi)}{\pi^2} \right].
\]

For the Maryland conversion data in the table above:

\[
Var(\theta) = 0.416^2 \left[ \frac{44/44^2}{1 + (71.29/105.19^2)} \right] = 0.0050.
\]
Safety risks at Traffic light installations

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Dr.-Ing. U. Frost/ Dr. BRENNER + MÜNNICH Deutschland

Complex of Problems

As a consequence of the growing density of traffic in urban areas time- and/ or vehicle-actuated traffic controls are more and more often used. In the case of the vehicle-actuated control it is necessary to distinguish between semi-vehicle-actuated controls, fully vehicle-actuated controls and “All-Signals-Red-At-Once-Green” controls. Within the research project in commission of the Bundesministerium für Verkehr (Federal Ministry of Transportation), flexible traffic light controls were examined for possible safety deficits. It was necessary to prove the following theory:

- It is suspected in the case of microscopic light control programs with flexible green periods that there is a higher safety risk, in comparison to fixed-time control for drivers who have local road knowledge during the change of signals (from yellow to red).

An unexpected red-light, or a denied green at an “All-Signals-Red-At-Once-Green”-light could lead to unexpected reactions of the road user. Possible conflict situations are emergency braking, rear-end collisions and running the red light. To compare flexible controlled and fixed-time controlled intersections, the afore mentioned types of conflict should been analysed.

The investigation contains a selection of traffic light controlled intersections in several German cities (e. g. Stuttgart, Würzburg and Aalen): two intersections with fixed-time control, 10 intersections with traffic-actuated control and 3 intersections with “All-Signals-Red-At-Once-Green” control. In a second measuring series at 2 intersections in Bremen, different control methods were tested under identical local conditions: fixed-time control, semi-vehicle-actuated control and fully traffic-actuated control.
Method of measuring

Safety deficits as a consequence of unexpected changes of traffic lights (Yellow-to-Red) are shown through single cars braking and the move-up time gap of the following cars. Throughout the deceleration, critical situations for individual cars can be identified. In the following manner the critical distance with insufficient time or way gap is dependent on the driving behaviour, the reaction time, the braking power, the starting speed and the local conditions. In order to achieve an objective description of the interaction between two or more cars, video was used to collect and describe the data of the time-distance curves. The recording grid was 25 pictures per second. A distance of about 50 Meters was observed in front of the stop line, cp. picture 1.

For a stopping time of about 4 seconds, roughly 200 individual pictures for analysing the time-distance curves are taken. The time-distance-data was registered on screen and further digitally processed. Considering the optical distortion, the preciseness was ± 1 Meter. In order to have equal surrounding conditions, only the measuring results at day-time and dry weather were taken.

An example of the time-distance curves registered in steps of 1/25 seconds are shown in picture 2.

The distances of following cars were taken over the whole measuring period and used to develop a matrix as shown in picture 3. The derivation of different safety levels is shown in the comparisons in picture 4.

Characteristic time-distance curves were analysed in the following number of cases:
- fixed-time controlled intersections, 55 cases of following cars
- fixed-time controlled intersections with adapted programs, 224 cases of following cars
- fully vehicle-actuated controlled intersections, 25 cases of following cars
- “All-Signals-Red-At-Once-Green” controlled intersections, 95 stopping individual cars
It was possible to obtain a sufficient number of measuring points with the video technique for the different controls in order to analyse the following behaviour during deceleration and acceleration as well as for yellow or red light runners. Through comparing this data, different levels of safety were recognised. In addition, the number of accidents, as collected by the police, were analysed for the intersections of focus.

**Results**

**Comparison of the cities**
During the change of signals there were partial differences in the distances in the compared cities but the course of the average distances were found to be independent of the measuring location although significantly influenced by the control method. This is why the results of the different cities could be aggregated and analysed according to the control method and if necessary, to the varied green periods.

**Control programs**
The comparison of the distribution of distances showed a clear dependence between the control method and the average distance for velocities over approximately 15 km/h.

The smallest average distances were measured at intersections with co-ordinated, fixed-time control because in this situation, an unexpected light change is especially surprising for car drivers, picture 4.

Traffic-actuated controls with longer green periods resulted in longer distances between cars in the case of flexible controls during the change of signals more than for fixed green periods.

Shortened green periods (usually due to giving priority to public transport) lead to shorter distances. Nevertheless, the risk for accidents in this case is smaller then with a fixed-time control. Unexpected changes of lights have to be checked for their effects on safety. The advantages of the traffic-actuated control to less flexible controls consequently becomes clear, cp. Picture 6.5.
The above mentioned results are also shown in the analyse of the rear-end accidents but cannot be confirmed due to the limited number of cases.

Deceleration
For a comparing safety assessment of all intersections, the deceleration of vehicles was analysed. It should be taken into account that the inclusion of the “All-Signals-Red-At-Once-Green” lights as traffic controls are usually used only as single lights for a small traffic volume and are not equally comparable with the control methods of the other intersections. The comparison criterion “deceleration” shows the highest values at intersections with fixed-time control and the lowest with “All-Signals-Red-At-Once-Green” control, compare picture 6.

The analyse of accidents with the lowest rate of rear-end accidents for “All-Signals-Red-At-Once-Green” controls (in combination with the small traffic volume at these intersections) confirms the findings.

From the results of the analyse, the following findings can be made:

• The traffic-actuated interruption of the time-distance co-ordination with an “unexpected red” traffic light is safer the more flexible the control method is.
• The use of fully traffic-actuated controls with no co-ordination of the neighbouring intersections alternate with a co-ordinated control leads to reduced vehicle distances and subsequently to a higher risk of accidents, if the traffic volume is higher and the traffic streams are directed.
• For a small volume of traffic and not co-ordinated single intersections, the “All-Signals-Red-At-Once-Green” control is suitable. This does not however apply for stretches with directed longitudinal traffic streams.

Further differentiating of the measured data, e. g. in respect to the traffic volume or the length of the green time, is not feasible due to the limited number of data.

To sum up, it can be said that a measuring and analyse method was developed which makes it possible to design and assess time-distances curves in the approaching zone of intersections.
The result of the research is, that (with respect to the adjustment to a new light control method) traffic safety will be improved the more traffic-actuated and flexible control method is. The selection of a control method is not exclusively limited on this criterion but e. g. has also to include the question of capacity and needs of co-ordinated traffic control. The result of the research demonstrates empirically that traffic-actuated controls can be, after a period of adjustment, less critical than fixed-time controls.

Literature

(1) Brenner, M et al.: Untersuchungen zu Sicherheitsrisiken an Lichtsignalanlagen durch den zeit- und / oder verkehrsabhängigen Einsatz von mehr als einem Steuerungsverfahren; Forschungsprojekt Nr. FE 77373/94 des Bundesministeriums für Verkehr, 1996

Fig. 1: Observation area video camera

Fig. 2: Time-position-curves of following cars approaching the stop line
Fig. 3: Derivation of different safety levels

Fig. 4: Mean distance of two following vehicles
Fig. 5: Traffic actuated controls with verified green periods

Fig. 6: Deceleration vs. distance to stop line
ABSTRACT

Assuring Safe Roadsides in Urban and Suburban Areas

by
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As many as one million highway crashes occur on the roadside in the United States every year. One third of all highway fatalities are associated with roadside crashes with societal costs exceeding $60 billion a year. Despite dedicated efforts over the past three decades, the roadside safety problem remains a major source of injury, death, and economic loss. The ever-changing characteristics of the vehicle fleet, driver population, traffic conditions, and highway environment make improving roadside safety a difficult task. In urban areas, the increased levels of traffic, the more frequent conflict points, existence of other modes of traffic, and varying land uses along the highway complicate the roadside safety problem. To date, little attention has been focused on the urban/suburban roadside.

A considerable amount of effort has been focused on roadside safety, but urban and suburban streets and highways have received only limited attention. NCHRP Project 17-13 "Strategies for Improving Roadside Safety" provided a comprehensive summary of means to improve roadside safety which were organized under five missions. These five missions were:

- Increase the awareness of roadside safety and support for it.
- Build and maintain the information resources and analysis procedures.
- Keep vehicles from leaving the roadway.
- Keep vehicles from overturning or striking objects on the roadside when they do leave the roadway.
- Minimize injuries and fatalities when overturns occur or objects are struck in the roadside.

This paper will use the goals, objectives, and actions that were identified in the plan to highlight tactics and strategies for improving roadside safety in the urban and suburban context.

The need exists to make the urban traffic engineer aware of potential roadside hazards and possible means to address them. Some of the aspects that will be covered include:

- Coordinating roadside safety efforts between municipal agencies.
- Building awareness of a safe urban roadside (e.g., minimizing roadside furniture, the hazards of poles)
- Considering the secondary consequences of roadside furniture on traffic movements and visibility.
- Information needs to monitor roadside problems.
- Processes for identifying urban/suburban roadside hazards
- The importance of clear sight lines.
- Role of maintenance in roadside safety.
- Opportunities for improved highway design and channelization.
- Users and uses of the urban roadside.
- Actions in education and enforcement that can improve roadside safety.
o Appropriate applications of roadside safety hardware.

The paper will focus on design, operations, and maintenance aspects for different types of urban and suburban highways. It will make recommendations for improved practices and offer insights to those involved in the safety management of urban/suburban streets.

Source: NCHRP Project 17-13 developed a strategic plan that provided a long list of goals, objectives, and actions associated with improving roadside safety. This paper will be based upon independent efforts by the author to extend the plan to a specific context and to identify specific tactics.
Session 11  Graduated Licensing, and Other Driver Education and Control Techniques

Rethinking educational content of driver licensing systems
*Nils-Petter Gregersen*

Youngsters on motorized wheels
*Per Hermansen*

Reaching for driver competencies rather than driving skills
*Hans Mattsson*

Describing traffic accident pattern during driver training – a base for preventive measures
*Hans-Yngwe Berg*

Do vision related renewal policies inhibit older driver relicensure?
*Melvin D Shipp*

Rethinking educational content of driver licensing systems
Gregersen, N. P. (VTI, Sweden), Hatakka, M. and Keskinen, E. (University of Turku, Finland)

During the last three decades there has been an enormous growth in knowledge about the reasons why young, novice drivers have been overrepresented in crash involvement. Much has also been done within the research area concerning applications of this knowledge in driver education and training. However, very few countries have introduced this knowledge into national curricula for driver licensing. There have been changes in licensing systems in several countries, such as the introduction of Graduated Licensing Systems, but these changes have focused on the organisational and structural aspects of the licensing, not much on the educational content and the specific competencies a driver needs. Many countries thus still use old-fashioned curricula where the frontline of knowledge has not been applied.

Within the EU-project GADGET (Guarding Automobile Drivers through Guidance, Education and Technology), a framework was developed for defining the competencies needed in order to become a safe driver. The framework was based on current knowledge and theories about driver behaviour and young, novice drivers. It was described as a matrix with four hierarchical levels of driver behaviour (vehicle construction and vehicle control, driving in traffic, plans for driving, goals for life) by three categories (knowledge and skill, risk increasing factors, self assessment). Within each cell of the matrix, a number of necessary safety related competencies have been defined. The presentation will, by using the example of Sweden, show how the matrix may be used in the renewal of a national curriculum.
«Youngsters on Motorized Wheels»

- A campaign running for ten years, ending in 2007
- Target group: 16 to 19 year olds
- The 3 elements of «Youngsters on Motorized Wheels»:
  a.) Accompanied driver training
  b.) «Speak out!» in the schools
  c.) «Speak out!» on the road
Aim:

To reduce the number of serious / fatal road accidents for the age group 16 to 19

The result in Telemark:

- So far unknown. But

- In another county, Sogn and Fjordane:

  The number of serious road accidents (with serious or fatal injury as result) among passengers went down by 30% over a period of 5 years after «Speak out!» was launched. This was an effect of «Speak out!».

Telemark poorer? Unlikely!

✗ «Youngsters on Motorized Wheels» in Telemark is run in close collaboration with Sogn and Fjordane.

✗ «Speak out!» is roughly two thirds of «Youngsters on Motorized Wheels». The last third is Accompanied Driver Training.

✗ On this background, we can hardly see any reasons inclining that the results in Telemark should become poorer.

✗ We will evaluate «Youngsters on Motorized Wheels», probably before 2003.
Accompanied driver training: The seminar

- All 16-year-olds get a personal letter, i.e. with their own name on it.
- The letter invites them to come to one of our evening seminars - together with parent or other driver companion.
- The subject of the seminar is Accompanied Driver Training. Agenda:
  - Rules and regulations
  - How to start
  - Where to begin
  - Safety precautions
  - Distribution of a booklet, a mirror, and an «L»
  - Etc.
  - Duration of the seminar: ca. 2.5 hours
  - The letter also emphasizes that we, as seminar leaders, want questions and dialogue: BYO questions!
  - This «customizes» the seminar, and is an active contribution to maximizing the learning output
  - In the middle of the session: Sandwiches, lemonade, tea or coffee. («social lubrication»)

- Sparsely populated areas: Application by post, e-mail, or phone
- Densely populated areas: Application in person
- Cities: The population of 16-year-olds are split alphabetically after family names, to form groups of a practical size
- Practical size will depend upon the assembly room, but to have a good dialogue, a number of roughly 100 persons (Norwegians) is a maximum.
- What would be «a practical group» of Americans?
The seminar: Practical philosophy

• We believe in positive reinforcement; i.e
  ✘ We want to make people feel that they mean a lot to us, and it is important to us that they come to the seminar - which is actually true
  ✘ We invite by name, i.e. personally, and with a hand-written signature
  ✘ We keep the invitation letter in an informal language
  ✘ Seminar leaders are experienced personnel, naturally equipped with well developed social antennas
  ✘ We customize the meeting (BYO questions)
  ✘ During the seminar, we frequently ask if there are «any questions, please?».
  ✘ Each question is dealt with in a serious way, with a positive smile
  ✘ We want to signal that we are really grateful for that particular question, and for the active attitude behind it
  ✘ Before the interval, we encourage the participants to discuss, and to form questions and give them to us, either in the interval, or after it
  ✘ «These questions will, without doubt, be of general interest, so we are very happy to get them …» etc.
In the interval, the participants and the seminar leaders mix, unformal groups are formed, and people discuss, or talk about whatever they want, relax, and have a good time.

After the interval, most of the «social ice» normally have melted, and the participants are more active.

We want people to feel that:

1. I can contribute a lot to reduce the risks of novice drivers by doing as much Accompanied Driver Training as possible before the driving-test!

2. Accompanied Driver Training is important to me and my family, and to the society!

3. Accompanied Driver Training is fun, and we can have «quality time» together while training!

4. I want to do this!

At the end of the seminar, we distribute

· A booklet about Accompanied Driver Training
· An extra rear mirror
· A magnetic / electrostatic «L»-sticker to put on the rear of the car while training

All is free of charge - the seminar, food and the goods.

We end the seminar with: «Good luck with the training sessions!»
«Speak out!» on the road

1. Informative control

2. Selective control
Information control point

- Post 1: Cars driven by young / novice drivers, or inhabited by the target group (16 to 19 year olds) are picked out. (Uniformed personnel from the police or The Norwegian Public Roads Administration, the traffic section)

- Post 2: Document / technical:
  - The driver's documents - drivers’ license, car registration documents - are checked.
  - Simple technical inspection: Does the lights light when they are supposed to? Do the tyres look all right? (Uniformed personnel)
  - «The impeccables» are urged to go on to post 3.
  - The rest are treated in accordance with normal procedures, by the police and Norwegian Public Roads Administration.
  - Whether they are asked to go on to post 3 or not will often be a matter of judgement - the main objective of this control is to give information. Just remember: Never kick first and give candy afterwards - that will puzzle anybody

- Post 3: Civilians (in the campaign T-shirt) are in informal dialogue with the target group. The video film is running all the time, giving background for the talking. Exhortations are never given. At the end of the conversation, T-shirts are handed out.

- Personnel: People from the Norwegian Public Roads Administration, the police, the schools, the insurance company, the organizations etc. - good mixers
Selective control

- Specific traffic controls = hoeing in the garden.
  - The reckless drivers, whom every policeman knows by name in his own district, are picked out, and dealt with / punished in accordance with the law (lose licence, fines, prison, their car is taken by the authorities, etc.). These controls are for the bad guys - the 10 - 15 % that do not listen or obey the rules.

- This is ordinary police traffic work.

- The traffic section staff of NPRA can assist, if desirable
«Speak out!» in the schools

- Is concentrated on senior high school (students 16 to 19 - i.e. the target group)
- All second-year-students shall have a «Speak out!» - session of 45 minutes - and in Telemark, they have
- Counselor:
  - A person from Norwegian Public Roads Administration, from the Police, the school system, or from one of the other partners
  - Dressed in ordinary clothes (i.e. no uniform).
  - Must be a person who can listen and talk with the students in a way that gives mutual confidence and respect.
- The «Speak out!» - coordinator at the school organizes practical details; makes appointments with the schools’ administration and the colleagues; arranges rooms, technical equipment (video and overhead), etc.
- At least one teacher should be present during the session, in a passive role. This is important, because:
• He or she shall get to know what the «Youngsters on Motorized Wheels» is all about

• He or she will learn about the basic philosophy of the campaign

• He or she will be enabled to support and encourage the students in taking on response for their own way of meeting social challenges and pressure; and to make the decisions that they find right

• He or she can, if convenient, use the same techniques when dealing with other subjects, like drugs, alcohol, harassing, etc.

• Dialogue, confidence and feeling of security are success factors

• Only in exceptional cases combine groups. If the students don’t feel safe and comfortable in the actual group they're in, they won’t talk - and there will be no dialogue

• Never gather the whole school, and run a «show»
«Speak out!» - rules:

• listen to the young
• respect their opinions
• let them themselves reason and formulate their own thoughts - don't push your «right answers» on them
• desired response = gratification. Any verbal response shall give positive signals in return
• let them discuss freely in the class - but let there be no insulting
• let the positive social pressure work
• only give the young the necessary support
• dare to be provocative to the group - but
• but be aware of and show respect to the limits each individual have
• be a «safe» adult - give them reason to trust you
• be honest, open-minded and interested
• dare to show honest commitment
• don’t try to act young and cool - anybody can see what you really are
• never moralize
• do not make «Speak out!» into a school subject
• natural, warm humour is always welcomed - but never be spiteful
• be aware that we work with trendsetting, and that we want to form the opinion - on a broadspected, long view
• consent to that this is a kind of work that is very exciting, challenging, involving, meaningful - or the opposite:
• what made you euphoric in one class, can make you hit the floor in another - because two groups never act similarly to the same responses
What is «Speak out!»?

- Based upon governmental plans for transport policy
- A campaign that try to change behaviour - not attitudes
- Systematical
- Aimed at a specific goal
- Long-ranged
- Clear in its message / philosphy
- Planned on a broad range of effects, use of media, etc.
- A cross-over project, where the Norwegian Public Roads Administration, the police, the schools / the teachers / professors, the organizations, and insurance work together - professors are on the road, the police are in the classroom, etc.
- Based on modern marketing and research
- In development. Conferences with assessment on recent work are run 1 - 2 times a year
A specific road safety campaign directed on teenagers aged 16 to 19, with the aim of reducing the number of killed or seriously injured, run by the Norwegian Public Roads Administration, Telemark.

The campaign «Youngsters on Motorized Wheels» consists of three parts, of which two have the same name and philosophy behind them, but are carried out on different arenas:

1. «Guided Practice»; i.e. driving practice with parents or other authorized person, before having taken the driver’s license
2. «Speak Out!» in the schools
3. «Speak Out!» on the road

Background

Telemark, or Norway, is unfortunately no exception when it comes to the pattern of serious or fatal road accidents: Teenagers aged 16 to 19 run a very high risk in the traffic, both as drivers and as passengers, on mopeds, motorbikes, or in cars - on «motorized wheels».

Inspired by international research, and by the «Speak Out!»-campaign in the county Sogn og Fjordane in West-Norway, the Norwegian Public Roads Administration of Telemark County in 1997 decided to try to change this, and in 1998 launched the «Youngsters on Motorized Wheels»-campaign.

The campaign involves Norwegian Public Roads Administration, Telemark, The Police, The Highway Police, the major Norwegian Motorists’ organization and traffic safety organization, an MC-organization, and The County of Telemark Traffic Safety Board, and, last but not least, a major insurance company. The partners have seats in the campaign board, and Norwegian Public Roads Administration, Telemark have the secretary functions.

How is it run?

«Youngsters on Motorized Wheels» has been run for 2 years now, and the results so far seem quite promising, as far as the practical work now starts to run smoothly.

1. From a very slow start, we had approximately 25 % of Telemark’s 16 year-olds with one or two parents on our «Guided Practice-briefings» in 1999. We believe that we will have more than 30 % this year.

2. In 1999, we visited all the 107 classes in Telemark with 17 year-olds, i.e close to all 17-years olds in the county. During our visit, which lasts 45 minutes, we have an active dialogue with them, inspired by a short video. Both the students and the campaign’s contact-teachers give us the feedback that they like the campaign and the way it is carried out. The contacts want to go on working with the campaign, and show enthusiasm.

3. In 1999, we tried a method on the road that didn’t work out very well, and we are now collaborating with the Police to change it to the better for 2000. We this year want to split the traffic control work on the roads in two:

   a) Information traffic controls (can be advertised, no secrets, everybody knows about them, and it is nice to get into one). These controls are for the good guys, the more than 80 % that do listen and behave.

   Post 1 (Police or Norwegian Public Roads Administration staff, in uniforms) picks out cars with young drivers. Post 2 (Police or Norwegian Public Roads Administration staff, in uniforms) checks your document and your vehicle (lights and tyres). If everything is OK with you, your documents and your vehicle, you are asked to go on to post 3, where the information people are - without any other uniform than the campaign T-shirt with logo). Here, you will get a nice chat, a smart T-shirt with a small logo on it, etc.).

On these controls, we had teachers on the information post. This turned out very positively: The teachers liked to meet the young people under other circumstances, and they could see that the campaign was more than what they had seen in their school; they met the police and others, and felt they were part of a team. The police, on their side, appreciated the teachers’ presence, much
for the same reasons; but in particular because they felt lack in their own competence in talking to / informing the teenagers.

b) Specific traffic controls. These can be compared with hoeing in a garden. The reckless drivers, whom every policeman knows by name in his own district, are picked out, and punished in accordance with the law (lose licence, fines, prison, their car is taken by the authorities, etc.). These controls are for the bad guys - the 10 - 15 % that do not listen or obey the rules.

The basis of the «Speak Out!» is that we actually know that roughly 80 % or more of the teenager population already do have all the needed knowledge and «socially correct attitudes» - what we want to do something about, is their behaviour. We believe that what people actually do in certain situations is what counts; not what they know they should have done, if not … . We talk to the passenger group, and to the trendsetters among the youngsters, not to the comparatively small group of more or less reckless drivers. If the latter group doesn’t listen to «the moral majority», they will have to face the possible consequences: No friends want to ride with them, they lose popularity, and they risk to lose their licence, and / or to be punished with fines, etc.

Also, it is essential that we in the «Speak Out!»-campaign never moralize. We want the dialogue with the teenagers, they must themselves find out what they want, take the responsibility for themselves and others, and then actually take the social control.

In the campaign, we try to think like the marketing people in the big companies. What makes people remember? It’s the reminders, the use of verbal and visual logos, linked up to some particular meaning, like «Levis’», «Coca Cola», etc. We therefore also run our films on television and cinema, and try to get the slogan «Speak Out!» repeated as often as possible in the media, etc.

The «Speak Out!»-campaign has been run with good results in Sogn og Fjordane for some years now. Also another county in Norway, Hedmark, has run this campaign, alongside with Telemark.

A network-group for «Speak Out!» has just been formed by the Norwegian Public Roads Administration on a national level, and we are a member here.

Last autumn, the Norwegian army decided that they want to use «Speak Out!», to get down the number of accidents where soldiers, on duty or on leave, are involved. Norwegian Public Roads Administration, Telemark is now 4 times a year at the Royal Norwegian Air Force School of Transport to run the video and talk with the guys, and the Royal Norwegian Army’s Transport Officer now works on a concept for the rest of the army, aware, however, of the fact that one should absolutely not start a campaign like «Youngsters on Motorized Wheels», or the part they want to use, «Speak Out!», without having the enthusiasm and material and human resources to keep it up. That is one of the main criteria for an effective campaign.

What we want to talk about, is the philosophy, the ideas of human interaction, and the practical and organizational sides of the campaign. With its simplicity, we think that the whole campaign «Youngsters on Motorized Wheels», or just the «Speak Out!»-part of it, can be of interest to road safety workers of several countries as methods of meeting the challenges of teenager-accidents in the traffic, or other challenges (drugs, sex abuse, etc.).

We would also like to draw your attention to the short summary of the «Speak Out!»-evaluation report of The Norwegian Institute of Transport Economics, which shows that, as a result of the «Speak Out!»-campaign in Sogn og Fjordane, the number of killed or injured car passengers reduced by about 30 %. Also, a very interesting cost-benefit analysis has been made for the campaign in this county. (Amundsen, Elvik, Fridstrøm: Effects of the «Speak Out!» road safety campaign on the number of killed or injured road users in Sogn og...
For more information, do not hesitate, but please contact me on one of the numbers / addresses below.
Reaching for Driver Competencies rather Driver Skills

A crucial part in setting up a system for driver examination is to decide on or to recognise the aims of driver education. What are the intentions with education and what do we hope to gain from such system. Is it maybe to produce

- a safe driver that never will make dangerous mistakes
  or is it
- a competent driver that will be able to avoid as many mistakes as possible
  or is it
- a skilled driver that will be able to handle the car on a high level of excellence, even when serious situations show up.

What is the difference? What can education possibly provide? How is driving tests affected?

The three concepts are intimately related to each other, but are still reflecting different aspects of the driving task.

A safe (or unsafe) driver will defined by his/hers actions later on in life, after getting the licence. (Which will not be possible to assess in advance). If a driver is going to be involved in dangerous situations or not is of course related to competence (achieved while a learner driver and later on by experience). But there are also to a lot of other factors that will have a crucial impact on the driver’s behaviour from time to time.

A competent driver is defined by his/hers abilities: abilities necessary, but not sufficient, to perform safely in future driving. Competence is by that reason seemed to be a more appropriate concept to describe the aims of education, at least if we talk about what is appropriate to assess in a driving test.

A skilled driver is defined by his/hers proficiency in handling the car or in performing specific tasks, carefully acquired by practice. This is often also referred to as manoeuvring skills or driving technique, and was from the start seen as the main purpose of driver training. To make and keep the car running and to keep it on road was by that definition what a good driver should be able to accomplish. Manoeuvring skills or driving technique can easily be assessed in specific manoeuvring tests or while driving in traffic.

Competence though is a very comprehensive concept, where driving skills just represents a small proportion of the important abilities needed for good and safe driving. Competence also includes a lot of other aspects, for example understanding of traffic, wise decisions, insightful judgements, foresight, and a good sense of responsibility.
To much concentration on just the skills, may be risky by at least two reasons:

- The learner driver may learn to rely too much on his/her own capability to manage situations that may occur. (over-confidence).
- The efforts to develop, for instance, communicative and cognitive abilities may be neglected.

The choice of viewpoint will make a tremendous difference in how to present the educational objectives in the curriculum, the way to achieve them and of course how you act in the control of the competencies reached and to what level they are developed.

The learning objectives can be described in different ways, as long lists of desirable and specific skills and behaviour in declared situations (as some models prescribed in the late sixties or the seventies) or more generally as comprehensive competencies necessary to become a safe driver in the future.

If we take the driving test as an example, it makes a great difference in how to arrange the test and also for the examiners decisions in how to act and what to judge.

- Will he look for proof of competence?
- Will he watch out for incompetence, lack of skills or the number of mistakes?
- Will he just tick of certain behaviours stated and listed on the test protocol?

The content and the procedures in assessment are known to have a great impact on the learning process, which makes it serious business for the examiners. The teachers, the supervisors and the student must understand and respect the demands for competence and proficiency that are expressed by the judgements made by examiners. Those judgements strongly affect education, both for good and bad.

Two things happened about simultaneously, a couple of years ago, in Sweden. A research project was started in order to find a simple model, easy to understand and communicate, to use for defining educational objectives and to remodel the practical driving test in accordance to that. The drivers licensing organisation was at the same time trying different models to get a more informative, valid and reliable way of conducting the driving tests. The model chosen for the test did show great similarities with the one presented by the research institute. They both
emphasised the benefits of thinking in terms of a few general, but important, competencies needed to be able to develop an effective, safe and cautious driving style.

By using a model based on general competencies for the test, the idea was that this would influence the education in the same direction. This is, in other words, something quite different from the models for education that is referred to as “competency based training”. Those models are often based on quite detailed descriptions of skills and sub-skills that are trained and assessed one by one until an appropriate standard is reached for each and every one of them. In our case we are talking about gaining the general competencies creating the ability to handle quite demanding and complex situations.

I will use the model presented by the research project to describe the main ideas before we go on to look at the driving test as it turned out to be.

This is the quintessence of the opinions of a number of well-reputed driving-school teachers, examiners and researchers in the field of education and educational measurement. They all agreed on that this was a quite simple way of describing important competencies for good drivers and that they were comprehensive enough to cover most of what is crucial for safe driving.

Traffic is a very complex system, where a lot of situations have their unique features. It is therefore necessary for a learner driver to get experience from different kinds of settings and to learn the specifics for each of them while still practising. Because of the strong relationship between what is tested and what is learnt, it is important that the driving test is carried out in a variety of conditions. By adding the categories of situations and circumstances that are used in the Swedish test to the model for competencies it is quite easy to illustrate both the difference and the connections between the two dimensions (see next page).

Looking on competencies and situations as a two dimensional spreadsheet, it is obvious that the same kind of competence is of used in all kinds of situations, even if the features and the importance of one kind of competence might vary depending on circumstances.
We will look a bit closer on those situations and circumstances before we go on to Swedish driving test as it is used in practice.

<table>
<thead>
<tr>
<th>CONTENT</th>
<th>COMPETENCIES TO DEVELOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Situations/Circumstances to master</td>
<td>Knowledge about the vehicle</td>
</tr>
<tr>
<td>1. Handling the vehicle</td>
<td></td>
</tr>
<tr>
<td>2. Driving in urban (built-up) areas</td>
<td></td>
</tr>
<tr>
<td>3. Driving in rural (non-built-up) areas</td>
<td></td>
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<tr>
<td>4. Driving in any kind of environment</td>
<td></td>
</tr>
<tr>
<td>5. Driving under special conditions</td>
<td></td>
</tr>
</tbody>
</table>

This figure is just showing the main groups of content. Each of those groups contains a number of situations and circumstances that might be included in a test.

The new driving test did use five categories of competencies instead of seven. Even if the concepts are not the same, they still quite good do represent the same properties of ability. The five competencies are serving as essential prerequisites to risk awareness (including perception) and in how to manage hazards showing up. Risk awareness and risk handling is therefor to be the all-embracing aspect for the assessment of all competencies. That is particularly stressed in the instructions to the examiners and in the information given to the candidates.

The five general competencies chosen for the test so far are:
- **Speed**, adapted to the situation
- **Manoeuvring**, physiological motor ability
- **Placement** on the road, assertive actions obvious to others
- **Traffic behaviour** like obedience of rules and planning in advance for the actions to take
- **Attentiveness**, related especially to treacherous situations

The assessment form used is shown in appendix (*layout slightly changed since that translation was made*).

The test is conducted according to the following in principles:

- Testing time, approximately 45 minutes
- Introduction and feedback shall be given
• Examiner is setting up each test (no fixed routes)

• Content
  - Parts 1-4 always represented in a single test
  - More than 50% of the time shall be spent on rural roads
  - Least time is to be spent on the handling of the vehicle
  - Compulsory items (due to EC-directives; safety check, manoeuvres)
  - Part 5 shall be included when possible
  - In 4 tests in a row, each of the points 1-45 (24 in total) shall be tested at least once, if possible due to the location

• A holistic judgement shall be made, referring to the 5 competencies defined
• Each point of content assessed must be noted on the assessment sheet, only if meeting the criteria
• When failing a test, the grounds for failing shall be noted, referring to the 5 competencies defined, as well as to the situations in which lack of proficiency was proven
• Copy of assessment sheet shall be given to the candidate (and the teacher)

The Main Features of the Swedish “Standardised Driving Test” – in summary

• **Competency based assessment**, which means looking for proof of competence rather than counting mistakes
• Competency is assessed mainly by the candidates behaviour in real traffic
• Competencies assessed are general in the sense that they are needed to some extent in every situation while driving
• The competencies are mainly assessed related to their expected power in risk awareness and risk handling
• Standardised mainly by equivalence in objectives to assess, less by uniformity in administrative routines during the test
• Dependence of (highly) qualified examiners
• High demands on national consensus about criteria
• Gives opportunities to evaluate
  —Content covered in the tests
  —Variety in test content for individual examiners
  —Differences between examiners due to content and pass rates
  —Quality of education due to main reasons for failing
  —Potential for different test locations
  —The need of in-service training or further education of staff
Temporary Driving Licence Permit

Valid only in combination with identification papers

Period of validity (see overleaf)

Official Examiner’s Signature

PER PEDAL

TEST No. 970918

COMPETENCY ASSESSED

Risk Awareness

Points 10 - 52: T = tested  F = failed

CONTENTS OF TEST

Part 1: Handling the vehicle

10

11 Safety check/Functional description

12 Parking

13 Driving in reverse

14 Starting on an incline

15 Using controls (blinkers, lights, wipers, etc.)

16 Efficient braking/Special braking test for motorcycles

Part 2: Built-up Areas

20

21 Driving in residential areas

22 Pedestrian/cycle crossings

23 Changing lanes

24 Street intersections

25 Intersections regulated by traffic lights

26 Roundabouts

27 Passing stationary vehicles

Part 3: Non-Built-up Areas

30

31 Changing directions of travel

32 Railway and light rail crossings

33 Pedestrians and cyclists (vulnerable road users)

34 Driving to a specific destination

35 Driving at road works sites

Part 4: Built-up Areas/Non-Built-up Areas

50

Part 5: Special conditions

51 Driving in darkness

52 Driving on slippery roads

Passed

YES NO

Test for

Automatic drive

Passed driving test

Failed safety check/functional description

Incompleted test

Examiner’s intervention

Failed specific manoeuvre test

Reg (plate)

Miscellaneous

Proof of identity papers

Test Location

5200 ÖRBro

123456-7890

TESTSSON. TESTIS

BAKGATAN 99

123 45 SMÅSTAD

Test Date

891231

4444

999

20.06

970918

1997-09-25
An Inquiry into a new Graduated Driver Education in Sweden

- Hans Mattsson, Swedish National Road Administration (SNRA)

In October 1997, the Swedish Parliament adopted a Bill called Vision Zero and the Safe Roads Society. The ultimate goal for the work on road traffic safety, stated by that Bill, is that no one should be killed or seriously injured as a result of an accident within the road transportation system.

One implication is that all those designing different parts of the traffic system have their own responsibility to make their tribute to traffic safety. That also includes educators, examiners, authorities, supervisors of the systems, policy makers and others who form the conditions for those trying to qualify for a driver’s licence.

As a consequence of this The Driving Standards & Licensing Division of SNRA has been working with an inquiry into a new graduated driver education system in Sweden during 1998 and 1999.

The work with the inquiry has been based upon some basic principles concerning driver training:
- a broader view of driver training
- development based on research findings
- educational process founded on a fundamental pedagogical idea
- safe and well-structured conditions during the learning process
- balance between private instruction and training with a professional instructor
- individual course layout possibility
- course length a crucial factor in learning
- same demands on learner drivers, regardless of age
- focus on safety
- more focus on reward than on punishment
- administrative and statutory support that makes the system clear and predictable
- social acceptance
- evaluation

The final proposals were presented to the Government in December 1999. Some of the characteristics of the proposed graduated driver education system are:
- Preparation before driver training starts (student and private supervisor)
- Educational period in three consecutive stages
- Progress checkpoints between each stage
- Minimum time in educational period (1 year recommended)
- Safety measures adapted to demands and capability in each stage
- At least one compulsory module in each stage (main roads, risk handling and first aid)
- Opportunity to practice alone during third stage.
- Final test (theory test and driving test) at SNRA
- Minimum age for practice driving is 16 years.
- Follow-up period (2 years), with measures targeted at drivers guilty of traffic offences.
Graduated Driver Education
- a way to better road safety for novice drivers

Summary of the Committee of Investigation’s proposal submitted to the Swedish Government in December 1999

Vägverket
Swedish National Road Administration
Driving Standards & Licensing Division
August 2000
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Why is a new driver education system necessary?

The Swedish Ministry of Transport and Communication proclaimed 1996 as the year of road safety. Several official inquiries focusing on road safety were conducted that year. One of these studied the very high accident risk to which newly licensed drivers are exposed. Hundreds of people are seriously injured or killed in accidents involving novice drivers. The question was whether it would be possible to reduce this risk through better driver education.

One conclusion of that inquiry was that minor adjustments to the present driver education system would not make any greater contribution to improving the prevailing accident and injury situation for new car drivers. Radical changes were needed. A relatively new approach to driver education is that it should extend over a longer period of time and be more systematically arranged (graduated) than the present system. This has been shown to have positive effects in several other countries. New Zealand, some territories and provinces in Australia and Canada as well as certain states in the USA educate new car drivers in this way, with good results. Although limited attempts at dividing the driver education programme into stages have been made in Europe as well, the whole concept of graduated education has not been tested on a full-scale level.

The results from the various inquiries were compiled by the Ministry of Transport and Communication in a memorandum (Ds 1997:13 "Towards the safe roads society"), which was referred for comment to a number of review bodies. Both the memorandum and the comments received were positive to the recommendation that a new graduated driver education system be elaborated.

The comments submitted in reference to the memorandum as a whole, combined with political considerations, formed the basis for the road safety bill presented at the end of May 1997 (Bill 1996/97:137 "Vision Zero and the safe roads society"). Parliament passed the bill in October 1997. On 18 December 1997, the Government decided, based on a decision of Parliament, to commission the Swedish National Road Administration (SNRA) to conduct an inquiry into how a Swedish graduated driver education system could be designed and introduced. The aim was to substantially reduce the injury risk and accident statistics for novice drivers.

The road safety bill proposed a new aim and direction for the work on road safety, based on Vision Zero. Vision Zero is an approach to road safety endeavours founded on the premise that no one should have to be killed or seriously injured as a result of an accident within the road transport system. Driver education was one of several key areas that was pointed out as essential in achieving a safe roads society. Hence, the inquiry was an element in the work focusing on the long-range road safety goal.

The relatively high risk of novice drivers injuring themselves or others in traffic was given as the most important reason for conducting the inquiry (see Figure1). Even though this risk does decrease the older the driver is when making his or her debut in traffic, it is nevertheless several times higher than for experienced drivers. Much further up in age, the risk increases again. The figure also shows that, on the whole, younger drivers are involved in a greater number of accidents than their older counterparts, perhaps because considerably older drivers tend to drive less and take shorter trips.
The social lifestyle of young newly licensed drivers makes them particularly vulnerable. Accidents involving young drivers often occur at night on weekends. These are often single vehicle accidents with high speed as a contributory factor. Several passengers are commonly found in the car. The drivers are often young men, and the cars are usually of an older model. The injuries in accidents where young people are involved are often more serious due to the fact that many neglect to use their seat belts and the cars are often older with fewer built-in safety features. While driving under the influence of alcohol does not appear to be common, those young drivers who actually have consumed alcohol are subjected to a considerably greater risk than impaired drivers in other ages (Gregersen, N P, 1996).

Fatal accidents in connection with overtaking or where pedestrians are involved are also common amongst drivers who have only had their licence for a very short time.

Two-thirds of those accidents causing injury that happen during practice driving occur on roads where the speed limit is 70 km/h or more. The most common kinds of accident are either rear-end collisions or those that occur at intersections. Nearly all accidents causing death that happen while practice driving have been on county, national or European highways where the speed limit is 70 km/h or higher. Single vehicle accidents and head-on collisions are the most common type here (Swedish National Road Administration, 1998-99).

**Present-day driver education**

The purpose of driver education is to promote road safety. In light of the fact that the risk levels are so much higher for novice drivers, it can hardly be considered that driver education up until the present has been sufficiently effective. In the past, driver education has focused on technical driving skills and mechanical knowledge about vehicles. For a long time, this was viewed as the most successful way to
achieve safe traffic behaviour. It took several decades before the driver’s role and the psychological aspects of driving were incorporated into driver education (Franke et al., 1995). With time, research has shown more and more clearly that a safe style of driving is characterised more by drivers thinking ahead and avoiding risky situations.

In 1993 new regulations permitted practice driving from the age of 16. An evaluation of this reform clearly indicated that the risk of being involved in an accident causing injury during the first years of driving is much less (about 25%) for those who had accumulated more experience as learner drivers (Gregersen, N P et al., 1998). For somewhat similar reasons the so-called ”graduated driver education systems” have been shown to significantly enhance road safety. This way of running driver education, in stages over a longer period of time, has been successful in those countries where it has been put into practice. These are some of the reasons for emphasising the importance of graduated driver education as an element in the work aiming at Vision Zero.

If a reform of the driver education system is to contribute to the attainment of the road safety goals, it must lead to fewer deaths and serious injuries in traffic, particularly where newly licensed drivers are concerned. This in turn means that better education must result in lower risks for this category of driver. Changes in the driver education system and/or other factors can entail novice drivers driving more, both as learners and immediately after having passed the driving test. It is therefore important that the risk is reduced enough to fully compensate for the increase in traffic casualties that otherwise can be expected as a result of more driving.

The SNRA’s assignment

The SNRA was commissioned to conduct an inquiry and propose how a graduated driver education system could be designed and implemented. This was to be done in co-operation with other public authorities and organisations concerned. The aim of the new educational system was that novice drivers would make their debut in traffic at a considerably lower level of risk than is currently the case. The work was to be based on an overall, long-term perspective. The SNRA was given the task of evaluating what had been experienced after the reform allowing practice driving from the age of 16 and incorporate this into the design of the new educational system.

In its inquiry, the SNRA was to

- review the requirements that should be placed on instructors and learner drivers in connection with private practice driving
- review the regulations concerning the driver education courses run by traffic schools, upper secondary schools, the adult education programme and the National Defence Force
- investigate the possibility of introducing stages and the need for new compulsory modules in driver education
- investigate whether first aid courses should be included as a compulsory module in driver education
- analyse the need to change the driving test, e.g. as to how it is conducted, test sites and technical equipment. Consideration was also to be given to whether driver education courses and driving tests could be run through the schools and by the National Defence Force according to the proposed regulations.
- examine whether and how a graduated driver education system
could be integrated into the administrative routines for driving licences.

The assignment also meant taking into consideration European Union directives as far as Sweden is concerned and assessing the impact if the recommendations are implemented.

How was the inquiry conducted?

The work was based on an overall approach to what is needed to ensure the efficient functioning of a new driver education system and for it to produce good results. Several important aspects for building up the system and many different factors that affect it were dealt with at the same time to enable the individual parts to work together in the best possible way.

The basic Inquiry was conducted through a central head project, supported by ten different satellite task groups working on the following specific issues:

- **Scientific support** for different analyses and recommendations
- **Scientific evaluation** of a new driver education system
- **External relations**, - information from and to the general public, stakeholders, the mass media and politicians
- **Cost and financing**, both for private persons and society
- **Regulation of professional driver education operations** at driving schools, upper secondary schools and within National Defence
- **Driver education with non-professional instructors**, prerequisites and requirements
- **Safety measures** during different stages of driver education
- **Organisation of driving tests** in a new driver education system
- **First aid courses** as an element in driver education
- **Management / Administration** in a new driver education system

A reference group closely followed the work of the Inquiry and made possible extensive discussions on the various matters investigated. This group consisted of 17 people representing different associations and interest groups that will be affected if the Committee’s recommendations are implemented. A steering group, comprising persons in positions of responsibility at the SNRA and the chairman of the reference group, issued the guiding principles for the work conducted in the inquiry. An interim report was submitted to the Government in December 1998 (STEFUS, 1998). The Committee of Inquiry’s draft final report was circulated for comment during the autumn of 1999. The SNRA submitted its final report to the Government on 21 December 1999.

Characteristics of a graduated driver education system

The graduated programme is founded on a basic concept within teaching that says that an individual’s learning must be built up gradually in stages, where such factors as personal experience, reflection and understanding are cornerstones. Indirectly this means that the educational process, seen in time and quantity, is of key significance for good results. Another important factor is safety. The pupil should not have to be
exposed to dangerous situations which he/she is not yet ready to handle. The most important characteristics of a graduated driver education system can be summarised as follows:

- **Focus on safety and gaining experience**
  Creating a well-structured course of education gives learners the opportunity to gain as much experience as possible before becoming an independent driver. The objective is to reduce the risk for newly licensed drivers.

- **Greater emphasis on reward than punishment**
  The basic idea is that reward is a more successful method than punishment for stimulating a person to complete a course of study consisting of several stages. This means that the system requires some kind of inherent incentives.

- **Increased risk exposure in line with greater competence and more experience**
  The basic premise here is that the prospective driver should not be exposed to greater risks than what he/she can handle depending on his/her level of maturity, competence and experience. This means that some kind of assessment must be made of the pupil’s development before being allowed to progress further.

- **Practice driving shall be encouraged, but under safe conditions**
  In order to be able to acquire as much experience as possible, the learner driver must be encouraged to drive. However, this is not to occur under conditions that could increase the risk of injury to him/herself or others in traffic. Hence, there are often different types of safety measures incorporated into the system. This principle is closely related to the one on increased risk exposure in line with greater competence (see above).

- **Focus on both the individual and his/her environment**
  This principle is based on two different conditions:
  - that it is the individual and his/her learning, level of maturity and experience that are the centre of focus,
  - that the pupil’s social and physical environment is a decisive factor in how to conduct the driver education programme and in the results achieved.

- **Supported by a well-developed professional driver education programme, parental involvement and other factors of positive influence in the community**
  The professional educational features that exist within the framework of the system, e.g., driving school courses or other compulsory elements, must be designed in the best way possible, both as regards content and pedagogy. Parental involvement, such as through driving practice instruction, is seen as another reinforcing factor. An articulated interest in road safety and an understanding of the value of good driver education in society is also expected to increase the potential of a graduated driver education system to achieve improvement.
Preliminary proposal by the Committee of Inquiry

In September 1999 the Committee of Inquiry referred a preliminary proposal for comment to some 40 bodies. The comments received and the general debate in society during the referral period were to be a guiding factor for making any adjustments or changes in the proposal prior to the SNRA submitting its final report to the Government.

The following describes the content of the preliminary proposal in general terms. Further details are given in context in the SNRA’s final recommendations.

Starting from a number of principles, the graduated driver education system is described as a systematic process that should be characterised by
- improved safety
- an extended assessment responsibility
- higher requirement levels
- social acceptance.

Various components in the system are described in more detail in the preliminary proposal, e.g.,
- preparatory courses for pupils and their instructors
- the different stages in the driver education programme
- the compulsory course modules
- safety measures, (both technical as well as regulations on where and how practice driving may be conducted)
- progress checkpoints
- driving test
- follow-up period

Various prerequisites that are important when building up the system, and necessary for its proper and smooth functioning, are also discussed in the proposal:
- a new course content, (a necessary adaptation to the changes in traffic conditions and current knowledge about education and road safety)
- administrative and legal conditions
- organisation of driving tests and test environments
- need to monitor how the system rules and regulations are followed
- certification of teachers and examiners
- placement possibilities for pupils with previous driving experience

In conclusion, a description is given of the potential consequences in the event of the proposal being implemented, in addition to how the implementation could be carried out and how the results of such a reform could be evaluated.

Analysis of the referral and debate

The preliminary report was debated intensively in the mass media, and the SNRA followed these discussions closely. Particular attention was focused on the following issues:

- **Increased cost** for learner drivers, which could lead to greater social inequality in the future.
- **Compulsory dual brake control** – questioned as regards its merit from a road safety perspective as well as whether the benefit could balance the cost.
• Minimum of 12 months – criticism against not being able to complete the programme in a shorter period of time, e.g. if a driving licence should suddenly prove to be a requirement for obtaining a certain job.

Changes in the proposal based on the comments received and the media debate

The viewpoints that were presented in the comments covered more of the proposal than what had been discussed in the media. All in all, both the general way of thinking as well as most of the recommendations in the Committee’s proposal were given support, even if certain points did meet with some misgiving or alternatives were suggested.

After having taken into consideration the comments and the views voiced in the media, the preliminary proposal was adjusted as follows:

• New form of preparatory course

There was nothing either in the public debate or in the comments received that spoke against the recommended compulsory preparatory course for pupils and private driving instructors, culminated by a theory test for the former group. However, the form of this course was changed to keep down the increase in cost. As far as pupils were concerned, more extensive traffic education in schools was proposed, the idea being that this would serve as a preparatory course. In the case of instructors, it was recommended that information manuals be developed for them instead.

• Length of the educational period still open

The recommended educational period of 12 months was not stipulated in the proposal. This matter was referred to the Government for review.

However, the SNRA still maintains that the length of the driver education programme is a highly significant road safety factor for novice drivers.

• Dual brake control to be investigated in greater depth

The Committee of Inquiry recommended that research projects be initiated aimed at learning more about the effect of dual brake control on road safety prior to proposing its compulsory use during private practice driving.

In this respect, comparisons can be made to the use of child safety seats, which eventually resulted in a law on protective devices for children in cars.

• Reduced costs

As a result of the changes in the preparatory course, more simplified progress checkpoints in the driver education programme and the elimination of compulsory dual brake control, etc, the estimated increase in cost was reduced from approximately SEK 4 000 to about 2 000 for the average learner driver.

Further, the SNRA recommends that an inquiry be made into whether it could be possible to allow a VAT exemption in connection with the expense involved for the compulsory course modules and progress checkpoints.

• Driving test

The driver education programme is concluded by a driving test. According to the preliminary proposal, this test was to be administered by SNRA staff. According to
the final proposal, this could also be conducted by persons employed within the National Defence Force or the school system, on the condition that they have been authorised to do so by the SNRA.

The SNRA’s final recommendations to the Government

On the whole, the recommendations presented in the Committee report that had been referred for comment still remain. The main points are described here. For more detail, reference is made to the various reports listed at the end of this report.

The SNRA’s standpoint in its final proposal submitted to the Government is that driver education shall be seen as part of long-term traffic education that starts early and continues throughout life. The SNRA has also ascertained that a radical change is needed if driver education is going to contribute to enhancing road safety in a more substantial way than what is the case today. This means that there must be a change in both the structure and content of driver education. This will also affect those parties involved in driver education.

In light of the foregoing, the SNRA recommends that the graduated driver education system shall be designed as follows:

- **Preparatory course of training for pupils.** This course should be one of the requirements for permitting the pupil to start actual driver education. This could be a general course on traffic education beginning in nursery school and continuing as a subject on the curriculum throughout the entire school period. This would mean that the prospective driver would already have acquired the fundamental set of values and basic knowledge needed to participate in road traffic prior to starting his or her driver education.

- **A higher level of relevant knowledge on the part of private driving instructors** will be demanded. The SNRA is not suggesting a compulsory instructor’s course at this point in time. Instead, information manuals should be produced and distributed to all private driving instructors upon their being approved in this capacity.

- **The driver education programme will comprise three stages with progress checkpoints in-between**

![](image-url)

**Figure 2: Simplified chart of a graduated driver education system**
This shall be characterised as follows:

- **This entire process shall not cover too short a time.** It is considered that at least 10-12 months is a suitable length of time for the entire educational period, regardless of the pupil’s age. A minimum length of time should also be stipulated for each stage. The SNRA leaves it to the Government to set the minimum length of time for the entire educational period.

- The length of the various stages should not be set until a new syllabus is ready.

- **Each stage shall have suitable safety precautions.** These shall be adapted to the level of proficiency that the pupil is expected to have attained in the different stages.

The following is recommended for the different stages of the educational programme:

### STAGE 1: Practice driving permitted with a private instructor or professional driving teacher
- on roads with a maximum speed limit of 70 km/h
- in less complicated traffic environments
- without passengers
- with an extra rear-view mirror and a sign indicating learner driver at stage 1

**Practice driving NOT allowed** under severe icy conditions

### STAGE 2: Practice driving permitted with a private instructor or professional driving teacher
- on roads with a maximum speed limit of 90 km/h
- without passengers
- with an extra rear-view mirror and a sign indicating learner driver at stage 2

**Practice driving NOT allowed** under severe icy conditions

### STAGE 3: Practice driving permitted with a private instructor or professional driving teacher
- in all types of traffic environment
- with an extra rear-view mirror and a sign indicating learner driver at stage 3

**Practice driving alone permitted (without a professional driving teacher or private instructor in the car)**
- if the pupil has passed all the progress checkpoints
- if the pupil has passed an accredited theory test (valid 1 year) conducted either by the SNRA or a test official authorised by the SNRA
- on roads with a maximum speed limit of 90 km/h
- if the pupil is at least 17 and a half years of age
- without passengers
- with a sign indicating learner driver at stage 3

**Practice driving alone (without a professional driving teacher or private instructor in the car) is NOT permitted**
- from 8 p.m. Friday and Saturday until 6 a.m. Saturday and Sunday as well as between these same hours on the night of a public holiday
There can be certain exceptions from these safety precautions in connection with professional driver education, e.g., with respect to having passengers in the car.

Practice driving alone is intended to provide a greater opportunity to acquire experience and develop more independence in driving. It shall also be seen as a means of encouragement at the end of the driver education programme, providing the learner driver with greater mobility at the same time.

- **Each stage shall contain a compulsory course module.** The following are proposed:

  (stage 1) **demanding driving situations on rural roads**
  (stage 2) **courses on high risk situations** (including driving in darkness as well as on icy surfaces)
  (stage 3) **first aid training**

The first two should be placed at the end of stages 1 and 2 and be a requirement for being permitted to progress to the next stage. These two elements should be seen as an introduction before being permitted to drive in more demanding traffic environments in the next stage. The third module can be completed at any time whatsoever during stage 3.

- **Progress checks should be conducted between each stage** by qualified educators (people in companies or organisations who have been approved by the SNRA)

- **The educational period is concluded with a driving test** conducted by a test official employed within the SNRA, the National Defence Force or the school system and who has been authorised by the SNRA.

- **There is to be a two-year follow-up period after completion of the driver education programme.** This is intended for newly licensed drivers who are guilty of an offence resulting in a formal warning or even in their driving licence being revoked. The follow-up will offer a more customised package of measures than what exists today. These measures will be adapted to suit the traffic offence committed by the new driver.

In order for it to be possible to build up the new system and have it work as envisioned, certain important conditions must first be fulfilled:

- **The course content shall be revised.** This is a key requirement in a new driver education system. A new course syllabus must be based on the changes in the role of the driver that has occurred in recent years as well as on modern theories concerning learning models and teaching methods.

- **The organisation of the driving test must be changed** to suit the new education system. This shall include:
  - *progress checkpoints* carried out by a qualified educator between the different stages in the educational programme
  - a *driving test*, a requirement for issuing a driving licence (theory and practical test) conducted by employees authorised by the SNRA.

Guidelines for the test content and the progress checks, and for how they are to be conducted, will be drawn up by the SNRA. This also applies to approval requirements. Practical checks and tests will be conducted in traffic environments that provide good conditions for being able to judge the driving skills that are to be assessed. This means that it is impossible to set up
common, simple rules for all checks and tests. The progress checks at the beginning of the programme can, for example, be conducted in relatively uncomplicated traffic environments, which will not suffice for the assessments that have to be made later on, or in connection with the driving test. Criteria on traffic environments that are to apply for different checks and tests will be elaborated by the SNRA.

- There must be a procedure of authorisation for those:
  - responsible for the educational content in the compulsory modules
  - conducting the compulsory progress checks between the stages in the course
  - conducting the final driving test (theory and practical), where this is not done by the SNRA’s own employees.

- There shall be a placement model for those with previous driving experience. It should be possible to place them in the graduated system at a level corresponding to their previous knowledge and level of experience.

- The education of professional driving school teachers should be lifted from its current placement in the upper secondary school programme for adults to the college level in order to expand teacher qualifications to suit a new educational system. This action is regarded as highly important, in part because the teacher is the intermediary link between the pupil and the goals in the educational programme. Such a course would also facilitate setting up different kinds of traffic education courses in the public school curriculum through more qualified teachers, something not available in today’s system.

- Current legislation concerning the revocation of a driving licence shall be applied or adapted to the system proposed where necessary. This applies first and foremost to the responsibility on the part of pupils, instructors and professional teachers as well as with respect to the recommendation on voluntary practice driving alone. In order for these rules and regulations to function as intended, it is important to introduce a smooth and efficient means of control to check adherence, and that legal action is taken against any violation in a serious manner.

- Current driving licence administrative routines shall still be applied or be adapted to the proposed system where needed. The necessary supplements to the present system chiefly concern how the progress checkpoints, the compulsory modules and the progression to the next stage in the educational programme will be documented and registered.

What are the implications if the proposal is implemented?

The SNRA has ascertained in its impact analysis that the system is thought to have a positive impact on road safety both during and after the driver education period. The number of hours of driving practice and the effect of the safety measures have been decisive factors in drawing these conclusions. The assessment has been based on such things as current accident statistics and the lower risk for newly licensed drivers that practice driving from the age of 16 has entailed. It has been assessed that there will be between 5 and 10 fewer traffic fatalities per year once the system has been developed. Different kinds of financial incentives would also strengthen the desire of newly licensed drivers to assume greater responsibility for road safety. This could
be worth studying in more depth, as regards car insurance for instance, in order to be able to link responsibility and benefits more to the driver than to the vehicle, as is the case today. The driver’s role and responsibility would then be much more clear.

The financial impact analysis shows that the proposed system could be socio-economically beneficial. However, it would be about SEK 2 000 more expensive for the individual. The ultimate cost depends on the pupil’s strategy in planning his or her driver education, and how car costs in connection with private practice driving are calculated.

The SNRA has proposed that an inquiry be conducted into whether the progress checks and compulsory course modules can be considered to lie within its area of responsibility, regardless of who conducts them. The cost could then be charged to the learner driver as a fee payable to the SNRA, which could thereby be exempted from VAT. This would limit the cost increase by a few additional hundred Swedish crowns. In its analysis, the SNRA has ascertained that in most cases there is sufficient private means to be able to finance driver education for young adults. Thus, it cannot be assumed that the graduated system would inhibit their being able to take part in driver education to any greater extent. It is important to note that driver education in Sweden is not more expensive than in other Nordic countries or Germany, and actually ranks amongst the least expensive.

The SNRA has also ascertained that having access to a driving licence is an important social consideration. Possession of a driving licence is commonly required for gainful employment. Hence, driver education should perhaps be seen as part of preparing pupils for the working world. The SNRA therefore recommends that an inquiry be conducted into the possibility of financing driver education through the student aid system. This could soften the economic burden that the expense nonetheless entails for certain people in society even today.

Better adaptation to the needs of different groups and individuals is considered important, particularly as regards the teaching. This can, for instance, apply to dyslexics or those with other learning problems. However, the SNRA maintains that the requirement levels must nevertheless be the same for everyone, even if special treatment can prove necessary in certain cases, e.g. in connection with tests and progress checks. This should be dealt with further on, once the system has been put into application and the problems have become more evident.

The length of time given as a minimum for the educational programme, about a year, can seem long at first. According to the SNRA’s way of thinking, it is important to try to change the outlook on driver education. On the one hand, the value in the education must be viewed from a life-long perspective. It must also be remembered that drivers are being educated for a highly demanding and complicated task in which the demands, and not least of all the level of risk, are many times higher than in most professions that require three years of education or more. Compared to the time that driver education takes today, the time period suggested appears quite reasonable. Of those who took their driving licence in 1998, fewer than 10% chose to complete their driver education in less than 6 months. Fewer than 25% had finished their education in less than a year (Vägverket 1999). It is also known that the group of people who decide to take a longer time for their driver education also run a distinctly lower risk of being involved in serious accidents. It is then not at all difficult to argue that the small group of beginner drivers who try to complete their driver education in the shortest possible time should also be given a reasonable chance to acquire the experience and understanding
that is needed to successfully cope with the initial hazardous years as a novice driver.

The educational consequences mostly concern the further education of those engaged in the educational programme. A partially new course content will demand changes in the qualifications of teachers and examiners. Added to this is a new structure for the educational programme and the need for greater adaptation to the specific individual. Hence, the SNRA would particularly like to point out the need for a driving teacher’s course at the college level, which, due to the recommendations of the Committee of Inquiry, is even more evident. Accreditation requirements, extended control functions, new course modules, etc all demand a broader level of proficiency.

The amount of practice driving, which ought to increase if the proposal is adopted, will be one of the primary environmental effects. On the other hand, the negative aspects involved in this can be counteracted by using a new course content as an instrument to increase the level of knowledge concerning environmentally-sound ways of driving and greater environmental awareness when choosing between various modes of transport.

The administrative and legal consequences are mostly a result of the need for transitional rules, the change in the conditions for private driving instruction, how to handle practice driving alone as recommended and the consequences involved in a follow-up period instead of a probationary period. These all require different degrees of statutory amendment, primarily to the Driving Licence Act and Driving Licence Ordinance.

The SNRA has ascertained that the proposal complies with the EC directive on driving licences (91/439/EEC) and that the placement model recommended can simplify matters for holders of foreign driving licences, or for anyone who has otherwise already acquired extensive driving experience, to be able to enter the programme at the right level within the graduated driver education system.

An analysis has also been made of the consequences for the National Defence Force and the school system. As regards the former, the system proposed is considered to enhance their being able to determine how far the prospective soldier has progressed in his/her driver education already at enlistment. The graduated structure of the system makes it easier to foresee how many will have a driving licence when reporting for active service or how far they have progressed in their driver education when it is time to do their compulsory military service.

It should be relatively easy to adapt the driver education course given in the "Vehicle Mechanics” programme in Swedish upper secondary schools to the graduated system without having to interfere with the course model that is applied there today. The SNRA recommendation that all employees involved in the test for a Category B driving licence should be appointed by the SNRA does not affect these persons to any greater extent. This procedure is already being introduced. It is more a case of emphasising the need for common quality enhancement from the situation today. The SNRA is of the opinion that there are great advantages to be had. This also complies well with the EC directive on driving licences, which states that a national body shall be responsible for ensuring that the driving tests in the country, as far as possible, shall meet high demands on uniformity and objectivity. According to the SNRA, the recommendation on test officials being appointed by the SNRA increases the chances that driving tests will maintain the same standard all over the country. Having the same further education programme and systematic monitoring of test operations increases the chance of this.
The role of the police will probably not be very different. It is not anticipated that the need to supervise traffic will increase in connection to the recommended rules for practice driving in the different stages of the driver education programme. The key issue is more working the new rules into the traffic supervision activities that the police conduct anyway in a manner that is taken seriously by the general public.

In conclusion, a plan is presented for how the system could be introduced and how the effects could be evaluated. The SNRA considers it important to implement a change in driver education gradually, with well-adapted transitional regulations in order to tone down that which could initially appear to be dramatic and revolutionary. This would also increase the chances of the proposal being accepted from the very beginning by most people in society. A well-planned implementation is also a prerequisite for being able to perform a carefully thought-out and objectively-based evaluation of the effects that the change in system would actually entail. Finally, the SNRA is of the opinion that any other trial activity than the one already mentioned, concerning dual brake control, need not be conducted.

Further information

A fuller, more detailed description of the recommendations is contained in the interim reports submitted to the Government in both 1998 and 1999. The appendices to the final report contain the Committee of Inquiry’s referral edition (Appendix 1), the comments received (Appendix 2) as well as the analysis of the comments including the SNRA’s deliberations, judgements and more detailed recommendations (Appendix 3).
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Abstract for oral presentation at Traffic safety on three continents, 20-22 September 2000 in Pretoria

Describing traffic accident pattern during driver training - a base for preventive measures?

During driver training in Sweden accidents happen both in private training with lay instructors and in traffic schools with professional instructors. Sweden has a long tradition of collecting information of road accidents. The police always investigate a severe accident and their information is kept at the National Road Administration and by Statistics Sweden. The data collected is time of day, place, weather condition, age, severity of injury etc. Since 1993 it is also possible to differ between accidents during driver training and other accidents. It is also possible to see if the accident occurred during training with a lay- or a professional instructor. This new the opportunities have made it possible to visualise a pattern within the accidents during driver training. If there is a pattern it could be used to develop countermeasures with the aim to prevent driver training accidents.

A study with the aim described above is ongoing and the result will be published during spring 2000. The study uses Correspondence analysis, which is an explorative statistical method made for finding patterns and relations between many variables at the same time. The analysis describes a pattern in a two- or three-dimensional space and the relation between the accident variables is visualised. The method could also be used in other countries then Sweden. For doing so it is important to inform about which accident data is needed for doing the analysis and how to interpret the result from the correspondence analysis. The result could then be used for developing measures for preventing accidents.
Do vision related renewal policies inhibit older driver relicensure?

by

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Key words: traffic safety, public policy, older drivers, vision testing, aging, prevention
INTRODUCTION

Traffic safety involves a delicate balance between the protection of individual rights, and ensuring the public's health and safety. Ideally, traffic laws should help reduce deaths, injuries, and economic costs associated with avoidable traffic crashes, without compromising the independence of others.

The average American driver is becoming older. From 1979 to 1989, the proportion of drivers 70 years of age and older increased by roughly 50%, whereas the number of drivers 19 years of age and under decreased by almost 20% [1]. By the year 2020, the number of elderly drivers in the United States is expected to increase by almost 50% [2]. Similarly, current demographic projections suggest a worldwide expansion in the proportion of elderly individuals during this millennium.

As a group, persons over sixty years of age have higher rates of vision impairment, and therefore may be at increased risk for vision-related crashes [3-12]. In the U.S., some states require vision testing for driver license renewal, whereas others do not [13]. Further, among those states requiring vision testing, the frequency and types of vision tests performed vary considerably. In light of this variability, it is possible that current U.S. vision screening policies may be ineffective in identifying at visually risk drivers.

It is also possible that current American driver vision testing criteria may discriminate against individuals with vision impairments. Since the elderly have higher rates of vision impairment, they are more likely to be denied driver licenses as a result of failing the vision screening examination [14-18]. Although vision impairments diminish driving performance, impaired drivers may change their driving behaviors and effectively compensate for these changes [19].

A 1998 study of vision testing policies and traffic safety determined that states with vision testing had significantly lower older driver traffic fatality rates than states without vision testing requirements [20]. According to this study, if mandatory vision testing had been required in 8 of the 10 states not requiring them, 222 lives could have been saved. The results of this study were consistent with other regional and national studies of this type [21, 22]. Although the results of this study suggest that vision related
relicensing policies fulfill their intended purpose of enhancing traffic safety, it is unclear whether there was a concomitant reduction in the number of elderly drivers in states with vision testing requirements.

The present research is an extension of the 1998 study. It investigates whether the proportions of older licensed drivers in states with vision testing policies were lower than in states without such policies.

METHODS

Multivariate statistical analyses of 1989-1991 traffic fatality and driver licensing data were performed. This statistical technique allows an assessment of the importance of vision-related driver license renewal policies while controlling for other factors associated with traffic fatalities among older U.S. drivers. State-level percentages of older licensed drivers (≥65 years) in vision testing and non-vision testing jurisdictions were compared, while controlling for factors associated with non-commercial driver license renewals. All 51 U.S. driver-licensing jurisdictions were included.

The goal of the analytical procedures was to derive a robust yet parsimonious model with which to assess the effect of vision testing policies on older driver relicensure. Prior to analysis, graphical diagnostic and formal statistical tests were conducted on all study variables to evaluate the study data (i.e., data errors, outliers, etc.). Remedial measures were used as necessary (e.g., transformation) prior to analytical modeling. An a priori alpha level (one-tailed) of .05 was established prior to data analysis.

Data for these analyses were derived from the 1990 U.S. Census, the Fatal Accident Reporting System, the National Highway Traffic and Safety Administration, the Federal Highway Administration, and the American Association of Motor Vehicle Administrators.

RESULTS

Multivariate linear regression modeling with forward stepwise and interactive stepwise regression selection procedures was used to control for reported and theoretical factors associated with state variations in licensed older drivers. A final model was derived and is presented in Table 1. Importantly, this model accounts for 74% of study variance.
Table 1: Multiple Regression Model for Prediction of the Percentage of Older Drivers (≥65 years) by licensing jurisdiction characteristics (one-tailed test).

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Independent Variable</th>
<th>Coeff</th>
<th>Std Error</th>
<th>Tolerance</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>Constant</td>
<td>-0.168</td>
<td>0.068</td>
<td>-</td>
<td>-2.474</td>
<td>.008 **</td>
</tr>
<tr>
<td>Vision Policy (V)</td>
<td>None vs. ≥1 vision test</td>
<td>0.004</td>
<td>0.005</td>
<td>0.952</td>
<td>0.839</td>
<td>.203 ns</td>
</tr>
<tr>
<td>Older Population (A)</td>
<td>% Population ≥65 yrs</td>
<td>0.010</td>
<td>0.001</td>
<td>0.855</td>
<td>10.39 6</td>
<td>&lt;.001 ***</td>
</tr>
<tr>
<td>Gender (G)</td>
<td>% Female Drivers</td>
<td>0.004</td>
<td>0.001</td>
<td>0.912</td>
<td>2.730 6</td>
<td>.004 **</td>
</tr>
<tr>
<td>Population Density (P)</td>
<td>log Population/mile²</td>
<td>-0.006</td>
<td>0.003</td>
<td>0.852</td>
<td>-2.133</td>
<td>.019 *</td>
</tr>
</tbody>
</table>

F(4,46) = 32.902; p < .001; R² = .741

ns = non-significant
* p <0.05
** p <0.01
*** p <0.001

As depicted in Table 1, vision related driver license renewal policies were not significant predictors of the proportion of older drivers for a given state. As expected, the proportion of older drivers in a state was positively associated with the percentage of older individuals. Also, consistent with the literature and theoretical considerations; the percentage of older drivers decreased as the population density increased, increasing proportions of female licensed drivers were associated with increasing percentages of licensed drivers, and per capita income was non-significant and therefore not included in the final regression model. No significant interactions between or among the independent variables were observed and therefore were not included in the final regression model.

In summary, the analysis of the proportion of elderly drivers (of all licensed drivers), in states with and without vision testing requirements revealed that mandatory vision testing requirements for relicensure, were not associated with lower percentages of older drivers. This implies that the mobility and independence of older individuals was not affected by state-level relicensure policies designed to identify, remediate, or restrict persons with vision impairments.
DISCUSSION

In the U. S., a driver’s license is intrinsic to mobility and independence. It is estimated that roughly 88% of older Americans rely on private automobiles for their transportation\textsuperscript{23}. This is not surprising since many states do not have the capacity to provide alternative means of transportation to private automobiles. Even in states with alternative means of transportation, many older Americans live in low-density communities where alternative transportation to the privately owned automobile is rare. Purportedly, a substantial proportion of older drivers continue driving until their ninth decade of life\textsuperscript{24}.

An inappropriate loss of driving privileges could have significant implications for older individuals, their families, and society at large. There is a clear need for nondiscriminatory, objective standards to guide those involved in legislating, regulating, and enforcing policies protecting the interest of both the individual and the public.

Governments have the right and responsibility to protect public safety, however, when shaping public policy, lawmakers, and regulators must carefully balance societal needs and individual rights. At issue in the case of driver relicensing policies, is whether contemporary vision screening protects the public safety to a greater extent than they reduce the quality of life of older Americans. The results of the present study suggest that current vision related license renewal policies do not unduly compromised older American drivers.
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Session 12    Road Accident Costs and Cost Benefit Evaluation

Road accident cost calculations in Estonia
*Peep Sürje*

Assessment of the relationship between 30 km/h zones and the surrounding major roads on traffic safety
*Guido Schuster*
ROAD ACCIDENT COST CALCULATIONS IN ESTONIA

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ABSTRACT

Following Estonia’s restoration of independence in 1991, the amount of cars has been rapidly increasing and currently there are on the average 394 cars per 1000 inhabitants. Despite the existence of a quite sophisticated road network (density 0.977 km/km², incl. public roads of 0.363 km/km²), the condition and traffic safety of the roads should be improved, thus a considerable investment is needed. In order to save money, the effectiveness of the methods applied should be evaluated. A substantial source of economy is road safety, in which Estonia’s situation compared with the Nordic countries is bad (102 accidents per 100,000 inhabitants). To evaluate the economy of traffic organization and cost benefits one needs to know the amount of losses caused by road accidents.

The methods for the evaluation of local road accident costs were developed in 1995 and reviewed in 1997. A third version is currently being specified in the light of the accumulated experience. Estonian methods were prepared on the basis of an analysis of the related EU methods made in 1994 (COST 313). The treatment costs of traffic accident victims, loss of production and decrease of human value as well as traffic-related property damages were primarily taken into account. Public statistics, data from traffic insurance and, for the purpose of evaluating human value, also interviews with people were used as source data. On the basis of the developed methods, the costs of road accidents were separately calculated for each year in the period between 1993 and 1998. Such an unorthodox solution was caused by the great changes experienced by the Estonian economy in that period: GNP decreased in 1993 ... 1994 and then started rapidly growing, nevertheless being significantly lower than in EU states. As economy becomes stable, in future the costs of traffic accidents can be derived for extended periods of time.

Costs of traffic accidents were calculated separately for killed, injured, and disabled persons and for traffic accidents that brought along only property damage. In making the related calculations the problem was not so much the interpretation of data as the obtaining of necessary data. For instance, in Estonia no separate accounts are kept for the duration of traffic accident victims’ treatment, therefore the average length of treatment of traumas was used. The exact amount of accidents that brought along property damages is not known either, as they need not be registered with the police. As far as the costs related to killed and disabled persons, the greatest share befalls the loss of production and loss of human value. With light injuries, the traffic-related property damage is the most substantial. The loss of human value was determined, besides interviewing people, on mathematical calculations based on the assumption that human value decreases in proportion to the lost incomes. Such an approach is novel as far as we know.
Comparing the costs of road accidents, as calculated in Estonia, those of the other European countries, there exist no substantial differences as far as the injured persons are concerned; the costs of the disabled persons are relatively high and those of killed persons relatively small. The cause of differences is primarily the difference in the development of the economic level but also the singularities of the methods used. Based on the amount of traffic accidents and the costs calculated in this study, the traffic accident related losses are estimated in Estonia to be approximately 190 million dollars a year, which is about 12% of the state budget.

1. INTRODUCTION

Since Estonia re-established its independence in 1991, the number of cars has increased at a rapid pace. To date this increase amounts to an average of 394 cars per 1,000 persons (Figure 1). Notwithstanding a developed network of roads (density 977 km/1000 km², incl. national roads 363 km/1,000 km²), the condition of roads and road safety needs to be improved, thus demanding substantial investment. From the financial perspective, the efficiency of the measures implemented must be valued in advance. One important source of potential savings is road safety. The state of road safety in Estonia is poor when compared with that of other Nordic Countries. Since 1992, when traffic was severely restrained due to economic difficulties, the number of deceased has been relatively constant at approximately 20 per 100,000 persons (Figure 2). However, the number of accidents and injured persons per 100,000 residents has undergone a steady increase (1996 was an exception). In 1999, there were 102 accidents and 117 injured persons per 100,000 residents, which was an improvement compared to previous years (Figure 2). Taking into account the increase in traffic, the total number of accidents per 10,000 vehicles has decreased (Figure 3). However, it is essential to keep in mind that only those accidents involving human casualties are officially registered as accidents in Estonia.
There are a number of possibilities available to improve road safety, starting from traffic education and ending with reconstruction of the road network. The efficiency and cost of these measures may differ on a considerable scale; therefore, the objective decision must proceed from economic grounds. In order to assess the efficiency of the traffic control measures, in addition to other economic indicators, it is important to realise the rate of damage caused by traffic accidents.
2. THE METHODOLOGY FOR DETERMINING THE COST OF ROAD ACCIDENTS

The methodology for determining the cost of road accidents was developed in Estonia for the first time in 1995 and was revised in 1997. According to the experience gained, adjustments have been made in this paper.

When preparing Estonian methodology, the analysis of methods used in the European Union performed in 1994 (COST 313) [1] was used as a foundation. The factors included in the calculation were primarily: medical costs of a victim, lost productivity, lost human costs, as well as, damage to property related to the accident. National statistical information and traffic insurance data were used as initial data, as well as, data derived from interviews conducted with the residents in order to place a value on human life.

On a temporal basis, costs related to road accidents may be categorised in two ways. First, a part of the cost is incurred at the time of an accident, or shortly thereafter (i.e., medical costs, non-medical damage to property, and administration costs). The loss of production and human costs will last over many years. During that time, productivity will generally increase and the costs incurred in the future have to be discounted to the present moment. Presuming the increase in productivity in geometric progression, the production in the year \( t \) will be

\[
A_t = A_0 (1 + i)^t
\]

Where: \( A_0 \) - production in the year 0 \((t = 0)\),
\( i = 1 + i \) - incremental ration of production.

At the same time, the current value of the discounted production \( A_t \) will decrease \( A'_t \), i.e.

\[
A'_t = \frac{A_t}{(1 + r)^t} = A_0 (1 + i)^t (1 + r)^t = A_0 \left( \frac{f}{g} \right)^t
\]

Where: \( r \) - discount rate,
\( \frac{1}{g} = \frac{1}{1 + r} \) - discount factor.

Gross production lost in lifetime

\[
\sum_{t=k}^{b} A'_t = A_0 \sum_{k}^{b} \left( \frac{f}{g} \right)^t = A_0 \left[ \left( \frac{f}{g} \right)^b - \left( \frac{f}{g} \right)^k \right] \frac{1}{1 - \frac{f}{g}}
\]

Where: \( k \) - number of years until restoration of capacity for work if an accident had not occurred,
\( b \) - number of years after an accident until eligible for pension.

Quantity \( k \) is relevant only in case of minors. In case of adults, \( k = 0 \), i.e., they already work. The formula applies in cases where \( \frac{f}{g} \neq 1 \). If \( \frac{f}{g} = 1 \), then
\[ \sum_{i=k}^{b} A' \_i = (b - k) A_o \]

Following the European model, 15 years of age is considered to be the pre-employment age. The cost of road accidents, both in other states and in this paper, have been calculated according to this model (in case of a person aged 16 years \( k = 0 \)).

In 1994, Estonia's retirement age for women was 56, and 61 for men. This age limit increases annually by half a year. The discount factors of different age groups have been calculated on the basis of the average age. Thus, in case of a deceased person aged 10 to 14, the period until his or her professional life would be \((m = 16 - 13 = 3)\) 3 years, and the retirement age in the case of men would be 53 and in case of women 48 years off the present moment.

However, the statistical data on residents and road accidents does not take into account the retirement age applicable in that particular year. Thus, without additional inquiries, we cannot know how many of the injured men aged 60 to 65, have already reached retirement age. To simplify the calculation procedure, age 65 in case of men and age 60 in case of women, have been adopted as average retirement age. Relatively few victims are injured immediately before retirement age and their lost employable period is short; consequently, an error made upon determination of retirement age has little effect on average loss of productivity (0.3% according to the data for 1995).

The age structure of men and women injured in road accidents involves significant differences. The number of injured men is considerably higher than that of women and the majority of injuries affect men aged 18 to 39. Injuries to women are equally distributed over all age groups; however, the period of 10 to 14 years of age is slightly more dangerous (Figure 4). The majority of both males and females having fatal injuries fall within this group (Figure 5). Male fatality rates are highest at the age of 25 to 29, for women it is after they have reached retirement age.

Choice of the discount rate presents a complicated problem; it influences significantly the amount of production not received from young persons having fatal injuries. In the case of senior age groups close to their retirement age, loss of production depends little on the ratio between increase in production and the discount factor.

In theory, the correct discount rate is derived from the income obtained from an alternative use of an investment. Income from interests paid on a deposit account, or the gross profit margin of any other project, could serve as alternative use. In this manner it would be possible to use the market rate of the bank (interest) rate as a discount rate. As in case of all projects, the gross profit margin should exceed the bank interest rate, the latter should be treated as the minimum value of a discount rate. The average interest of deposits has continually decreased in Estonia in conjunction with economic stabilisation. In 1993, the average weighted annual interest was 3.39%, in 1994, it was 2.74%, and in 1995 it amounted to 2.57%. In other European states, discount rates of 0 to 7% have been used upon costing road accidents, which presumes a minor rate of inflation.
Figure 4. Injured by age

Figure 5. Killed by age
In theory, the correct discount rate is derived from the income obtained from an alternative use of an investment. Income from interests paid on a deposit account, or the gross profit margin of any other project, could serve as alternative use. In this manner it would be possible to use the market rate of the bank (interest) rate as a discount rate. As in case of all projects, the gross profit margin should exceed the bank interest rate, the latter should be treated as the minimum value of a discount rate. The average interest of deposits has continually decreased in Estonia in conjunction with economic stabilisation. In 1993, the average weighted annual interest was 3.39%, in 1994, it was 2.74%, and in 1995 it amounted to 2.57%. In other European states, discount rates of 0 to 7% have been used upon costing road accidents, which presumes a minor rate of inflation.

As a rule, the incremental ratios of production remain below the discount factor (1.0 to 1.024), due to which the ratio \( f/g \) is normally below 1.0.

The annual interests of deposits have also decreased. The least that could be accounted for as a discount factor are the interest rates of transaction deposits. In this paper, the ratio between increase in production and discount factor has been calculated using the following formula:

\[
\frac{f}{g} = \frac{(P_{pl}/i_{i})(P_{p0}/i_{0})}{(1 + d/100)}
\]

Where: \(P_{pl} \) and \(P_{p0} \) — the gross domestic product in fixed prices during the year under inspection and the previous year,
\(i_{i} \) and \(i_{0} \) — number of people capable for work during the year under inspection and the previous year,
\(d \) — average interest of bank deposits, in per cents.

In 1993 the relevant ratio between increase in production and discount factor was 0.88, in 1994 it was 0.97, in 1995 1.028, and in 1996 1.026. The ratio between increase in production and discount factor was also taken as the discount factor with regard to loss of production. Such a choice does not differ from those used elsewhere in Europe.

According to the developed methodology, the road accident costs were calculated separately for each year in 1993 to 1995. Such an unusual solution was caused by the critical changes occurring in the Estonian economy during that period; namely, there was a decline in gross domestic product during 1993 to 1994, followed by a rapid increase. Nonetheless, the end result remained considerably below the average level of the European Union member states (Figure 6). The method of calculation presumed that the economic growth achieved during the previous year would continue to increase over a long period, and that such an approach was appropriate from 1993 to 1996. In 1997, Estonia experienced an unpredicted conspicuous period of economic growth. As a result, the annual increase in gross domestic product was over 8%, followed immediately by a two-year recession caused by economic depression in Russia. It would have been clear even without the recession in 1998 that Estonia's economic growth could not continue to be as impressive over a long period of time. Thus, it would be more accurate to take into account not only the economic growth of
the previous year, but also the economic growth of a more extensive period. In our calculations the period duration was equalized to three years (Table 1).

![Figure 6. Gross domestic product per able-bodied inhabitant in USD](image)

The ratio between productions increases and discount factor

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>$f/g$</td>
<td>0.885</td>
<td>0.968</td>
<td>1.028</td>
<td>1.026</td>
<td>1.072</td>
<td>1.022</td>
<td>0.951</td>
</tr>
<tr>
<td>Average $f/g$ since 1993</td>
<td>0.885</td>
<td>0.926</td>
<td>0.959</td>
<td>0.975</td>
<td>0.994</td>
<td>0.998</td>
<td>0.991</td>
</tr>
<tr>
<td>Average $f/g$ of 3 previous years</td>
<td>0.885</td>
<td>0.926</td>
<td>0.959</td>
<td>1.007</td>
<td>1.042</td>
<td>1.033</td>
<td>1.007</td>
</tr>
</tbody>
</table>

Once economic stability has been established, it is possible to deduce the cost of road accidents for a longer period. Previously, the cost of road accidents was calculated separately for the deceased, injured or disabled, and accidents involving only damage to property. In performing the necessary calculation, it was not the interpretation of data that presented a problem but rather the provision of the required data. For example, separate records are not maintained in Estonia regarding the duration of medical treatments of those injured in road accidents, due to which the average period of trauma treatment was used instead. The precise number of road accidents incurring damage to property is not known either because such accidents need not be registered with the police.
The largest part of the cost in the case of the disabled and deceased is taken up by loss of production and human costs. In case of minor injuries, the major cost entailed by accidents is damage to property. In addition to the interviews, human costs were also determined by calculation, which presumed that a person has, apart from productive capacity, human cost (the value of which certainly decreases as a result of an accident). The decrease in this cost has been assessed primarily through willingness to pay. The maintenance expenses of a 100% disabled person until his or her likely death could be taken as human cost. So these are costs incurred by the society to provide for a disabled person. Such an approach inadequately clarifies evaluation of human cost in case of the deceased, due to which our calculation proceeds from other bases.

Proceeding from the method of lost lifetime years, one may presume that the amount of a person’s benefits in life largely depends on his or her income. At maximum, he or she may spend his or her entire income. If he or she becomes disabled, his or her income decreases considerably, resulting in a decrease in the demand for social production. Such a decrease in income from the moment an accident occurred would represent the decrease in human cost in case of disability. The lost income should also indirectly characterise the suffering and decrease in the quality of life for the person. Discounting of human cost also presents a problem just as loss of production. To date, income (salary) has increased more rapidly than gross domestic product and pensions. This may continue over a limited period of time, but not long, due to which the discount factor of salary should be less than or equal to the one used upon discounting gross domestic product.

Lost income per one disabled person:

\[ w_i = 12(e - e_v)(1 + p_i) v_i + p_v(e_v - e_i)/V \]  

Where:  
- \( e \) - average salary, EEK per month,  
- \( e_v \) and \( e_i \) - old-age pension and invalidity pension, EEK per month,  
- \( p_v \) - number of injured pensioners.

Discounted value of lost income of a disabled person in current prices:

\[ W_i = w_i \sum_{i=1}^{b} (f/g)_i \]  

Where:  
\( \sum_{i=1}^{b} (f/g)_i \) - discounted total of injured persons.

Insurance compensates for a part of the costs incurred by a disabled person that must be deducted from the lost income. The result obtained can be viewed as lost human costs.

Lost income per one deceased person:

\[ w_h = 12(e(1 + p/i)v_i + p_h e_v)/H \]  

Where:  
- \( p_h \) - number of deceased pensioners.
Discounted value of lost income of a deceased person in current prices:

\[ W_h = w_h \sum_{h}^{b} (f / g)_h \]  

Where: \( \sum_{h}^{b} (f / g)_h \) - discounted total of the deceased.

Other calculation methods of lower costs will not be discussed in this paper due to the limited size of the paper, although the following table provides a brief overview.

**TRAFFIC ACCIDENT DAMAGES**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>Deceased, $ per person</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Family pension</td>
<td>0</td>
<td>79</td>
<td>392</td>
<td>1,351</td>
<td>6</td>
<td>184</td>
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<tr>
<td>Burial cost</td>
<td>112</td>
<td>178</td>
<td>328</td>
<td>393</td>
<td>525</td>
<td>639</td>
</tr>
<tr>
<td>Discounted loss of production</td>
<td>12,685</td>
<td>41,272</td>
<td>171,37</td>
<td>175,55</td>
<td>343,40</td>
<td>265,31</td>
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<td>Lost human costs</td>
<td>6,424</td>
<td>24,735</td>
<td>114,40</td>
<td>117,58</td>
<td>219,49</td>
<td>170,11</td>
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<td>Damage to property caused by road accident</td>
<td>1,087</td>
<td>1356</td>
<td>1,685</td>
<td>1,775</td>
<td>1,784</td>
<td>1,801</td>
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<tr>
<td>Total</td>
<td>20,308</td>
<td>67,620</td>
<td>288,18</td>
<td>296,65</td>
<td>565,21</td>
<td>438,04</td>
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<tr>
<td><strong>Disabled, $ per person</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medical costs</td>
<td>7</td>
<td>119</td>
<td>102</td>
<td>159</td>
<td>116</td>
<td>125</td>
</tr>
<tr>
<td>Benefit for incapacity for work</td>
<td>0</td>
<td>77</td>
<td>109</td>
<td>161</td>
<td>81</td>
<td>125</td>
</tr>
<tr>
<td>Invalidity benefit</td>
<td>0</td>
<td>1,332</td>
<td>19,544</td>
<td>42,450</td>
<td>35,458</td>
<td>954</td>
</tr>
<tr>
<td>Loss of production during medical treatment</td>
<td>240</td>
<td>307</td>
<td>337</td>
<td>367</td>
<td>380</td>
<td>423</td>
</tr>
<tr>
<td>Discounted loss of production</td>
<td>13,291</td>
<td>48,462</td>
<td>197,51</td>
<td>222,81</td>
<td>380,19</td>
<td>320,64</td>
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<tr>
<td>Lost human costs</td>
<td>5,138</td>
<td>21,828</td>
<td>82,990</td>
<td>67,163</td>
<td>145,20</td>
<td>156,45</td>
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<tr>
<td>Damage to property caused by road accident</td>
<td>914</td>
<td>1,303</td>
<td>1,536</td>
<td>1,560</td>
<td>1,540</td>
<td>1,557</td>
</tr>
<tr>
<td>Total</td>
<td>19,590</td>
<td>73,427</td>
<td>302,13</td>
<td>334,67</td>
<td>562,96</td>
<td>480,28</td>
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<tr>
<td><strong>Injured, $ per person</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Medical costs</td>
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<td>1,536</td>
<td>1,560</td>
<td>1,540</td>
<td>1,557</td>
</tr>
<tr>
<td>Total</td>
<td>1,160</td>
<td>1,805</td>
<td>2,084</td>
<td>2,246</td>
<td>2,117</td>
<td>2,230</td>
</tr>
<tr>
<td>Damage to property only caused by road accident, $ per accident</td>
<td>1,302</td>
<td>1,847</td>
<td>2,115</td>
<td>2,120</td>
<td>2,236</td>
<td>2,288</td>
</tr>
</tbody>
</table>
3. CONCLUSIONS

- It is evident from the data presented in the table 2 that in several years, the costs of the disabled exceeded that of the costs of the deceased. The difference is caused primarily by the different structure of the deceased and the disabled. In most cases, the disabled persons are younger, due, to which the reduction in productivity due to accidents is larger. In 1998, according to the data presented by Estonian traffic insurance, there were fewer people disabled by automobile accidents than in other years. As a result, the average cost per casualty and per accident decreased in Estonia.

- When comparing the costs per accident calculated in Estonia, with the ones calculated in other European states, there are no significant differences with regard to persons receiving minor injuries; the costs of the disabled are relatively high in Estonia and the costs of the deceased low. The differences are caused, above all, by the difference in the level of economic development of the states, which when judged on the basis of the purchasing power, the standard is nearly 2 times less than it is in the poorer EU member states. Another cause is certainly the particular features of the methodologies applied, due to which the costs related to disability are relatively high in Estonia.

- Proceeding from the number of road accidents and the costs calculated in this paper, the estimated cost of road accidents in Estonia in 1998 was approximately 190 million USD, which is about 12% of the state budget and 3.6% of gross domestic product. The costs related to road accidents exceed the investments into road management by more than three times.

REFERENCES

Assessment of the Relationship between 30 kph-zones and the Surrounding Major Roads on Traffic Safety

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1 Introduction

Traffic calming especially on major roads is under increasing discussion in Germany. The discussion is pushed by the Federal Department of the Environment and the German Board of Cities for environmental aspects and the increasing numbers of children fatalities. In Germany the effects of 30 kph-zones on traffic safety and the environment were researched directly by accompanying investigations. In several model areas an improvement of traffic safety was found out. But either the researches focused only the traffic calmed area itself or the traffic safety of the traffic calmed area and the surrounding major roads were only taken into consideration without any differentiation. A direct comparison was not carried out and only some contradictory and not very clear results can be drawn from these studies. The former investigations shows that the speed in 30 kph-zones – e.g. the speed $V_{85}$ will be reduced in the range of minus 9 to minus 22 percent.

But these researches does not deal with the speed on the surrounding major roads and the development of the accident there. Figure 1 shows the results of the speed and accident evaluation of former investigations. The contradictory results except for the data of Mainz are distinct. Although the areas in the other towns have a better $V_{85}$-acceptance their number of fatalities and casualties increases. Especially this results have motivated to investigate the surrounding major roads and their relationship to 30 kph-zones in more detail.
Figure 1

<table>
<thead>
<tr>
<th></th>
<th>Improvement of V85-Acceptance</th>
<th>Alteration of Number of Fatalities and Casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamburg</td>
<td>0</td>
<td>-10</td>
</tr>
<tr>
<td>Darmstadt</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>Esslingen</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Ingolstadt</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Mainz</td>
<td>34</td>
<td>-26</td>
</tr>
</tbody>
</table>

2 Method

In the beginning of the research three working hypotheses were drawn up to get a clear procedure and to deduct the necessary evaluation criteria. The hypotheses are: 1. The higher proportion of exceeding of the low speed limit in 30 kph-zones causes a worsening of the traffic behaviour at the surrounding major roads with a high exceeding of the speed limit; 2. The speed limit of 30 kph in the zones is supported usually by structural measures. The motorists feel to be dictated and get more aggressively on the 30 kph-zones roads as well as on the surrounding major roads. This effect causes higher number of accidents and accident severity; 3. The safety of the cyclists and pedestrians decreases on the major roads by the changed traffic behaviour of the motorist. The gain of traffic safety in the 30 kph-zones have to be compared with the loss of safety on the major roads.

The hypotheses show which evaluation criteria have to be used. The accident occurrence was analysed for an area-wide and objective assessment of traffic safety. Moreover the speed was taken into account, because it represents an additional marker for traffic safety. Exceeding the speed is one of most frequent accident causes. The evaluation bases on a simple before and after study for the domain of accidents and speed. It is very important for the assessment that other effects that might influence the traffic safety are constant or that
the effect can be estimated and such be taken into account of the analysis. Only on this basis the observed effects can be related to the 30 kph-zone. A before-and-after analysis with a control group or area was not possible, because it would have been necessary to have comparable situations in the 30 kph-zone as well on the surrounding major roads. Such situations were not found. To compare the accident occurrence the accident density and especially the accident cost density was taken as relative evaluation criteria. The density criteria are more appropriate for the evaluation of the both categories – the zone and the major roads - as the quite common used accident rate. The research area was abstracted by seven net elements (see Figure 2): the section of a major road and of a zone, the zone intersection, the intersection without any link and three types of intersections with link, the three or four leg intersection in the running of a major road and the edge intersection with link. It seems to be a five leg intersection but in reality the approach is located in a distance of about 20 m from the stop line, so this intersection was defined as a one with link. Especially these three intersections influence the relationship between major roads and the zone.

Figure 2
It is necessary for the analysis of the relationship to have a clear classification to a major road or to the zone, especially at the intersections with a link. The classification was carried out by the principle of the main accident responsibility.

3 Researched Areas

The research bases on two residential areas in the City of Darmstadt. Area 1 is situated directly near at the inner city. It is characterised by block buildings from the turn of last century. The area is very high compacted with insufficient parking space. The street net is grown without any masterplan. Area 2 is situated at the outskirts of Darmstadt. It shows a complete other structure and is characterised by family houses. The streets are designed regularly in contrast to area 1. The two areas have nearly the same number of net elements (see Figure 3).

As often in the case of statistical accident evaluation the sample size is not too much for a statistic with a confidence level of 95 %. So the samples of the two areas were put together to get a covered statistic.

Figure 3

<table>
<thead>
<tr>
<th></th>
<th>Intersections</th>
<th>Sections</th>
<th>Intersections with Link</th>
<th>Sections</th>
<th>Intersections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>3</td>
<td>17</td>
<td>16</td>
<td>62</td>
<td>29</td>
</tr>
<tr>
<td>Area 2</td>
<td>1</td>
<td>12</td>
<td>17</td>
<td>69</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>29</td>
<td>33</td>
<td>131</td>
<td>64</td>
</tr>
</tbody>
</table>
4 Results

The basis of the evaluation is a sample of 1160 accidents with about 2300 involved road-users. The number of accidents gives a first impression of the accident occurrence (see Figure 4). For all road categories except for the category 30 kph-zone intersection with link the number of accidents decreases between 13 % and in the best case of -31 % for the major road section. For the 30 kph-zone intersection with link the number increases by 105%. It means that for this category the main responsibility for an accident is situated in the secondary street – here the 30 kph-zone.

Figure 4

![Number of Accidents](image)

The relative alteration of the frequency distribution gives some more detailed information (see Figure 5). The increase for the category 30 kph-zone intersection with link is confirmed with a plus of 5%. But moreover it is obvious that a negative development occurs as well at the intersections in the 30 kph-zone itself. The increase is 2%.

The accident type distribution can help to clarify the reasons for the accident development (see Figure 6). The most remarkable alterations were made out for the accident types 2, 3, 5 and 6. There seems to be a connection between type 2 and 3 for the major roads and the intersections with link and a connection between type 5 and 6 for the 30 kph-zone itself. After implementation of the zone the proportion for type 5 in contrary to the proportion of
type 6 decreases. Restricting the cross-section reduces the speed but this measure evokes conflicts with parking vehicles. A general shift of accident type 2 to the type 3 was evident. Implementation of the zone might causes an increase of the turning off manoeuvre in favour to the turning in manoeuvre.

**Figure 5**

![Alteration of Number of Accidents between Before and After-Period](image1)

**Figure 6**

![Alteration of Accident Types between Before and After-Period](image2)
The accidents were analysed by the accident severity on one hand for fatalities and casualties (AFC) and on the other hand for accidents only with damage (AD) to get further information about the effects of the applied measures (see Figure 7). A distinct decrease in the major roads of 34% (AFC) and 13% (AD) and in the 30 kph-zone of 15% for the accidents only with damage were evaluated. These results had been expected. But an eccentric result was observed for the group AFC in the 30 kph-zone, an increase of the AFC-number of 35% appeared for the real target group.

**Figure 7**

![Number of Accidents for the Categories AD and AFC](image)

AD := accidents with light and severe damage   AFC:= accidents with fatalities and casualities

A view on the accident costs shows more clearly the development (see Figure 8). It has to be realised that the gain of costs for the group AFC in the major roads is totally compensated by the loss of costs in the 30 kph-zone. The gain for the AFC is about 0.55 million DEM and the loss is nearly the same with 0.56 Million DEM. Nevertheless an clear improvement of the overall accident costs by a considerable reduction of the accidents with damage in the major roads was noticed, in total the reduction is about 13 %.

The view on the accident cost density is necessary to compare this results with those of former researches (see Figure 9). The density for the major roads as well as for the zone is on a plausible level. The figure shows clearly the even more positive effect of accident improvement on the major roads when considering the higher density level in the zone. An improvement on the major roads is very effective because of its high density level.
In traffic safety analysis an isolated evaluation of 30 kph-zone is clearly not sufficient, so the traffic safety development in the whole was taken into account. *Figure 10* shows the relative alteration concerning the before- and after-period of the accidents costs. It is differentiated
between the total alteration in the City of Darmstadt, the surrounding major roads and the 30 kph-zone. This comparison can be made because the proportion of the evaluated accidents of the research is a range of 4 to 6% of accidents in Darmstadt. The influence can be neglected considering the complete development in Darmstadt. The general development for the accidents with fatalities and casualties is much better in the whole city of Darmstadt than in the research zone and their surrounding major roads. On this basis the traffic safety have to be appraised as poor. If the zone alteration of the AFC is referred to Darmstadt development, the increase is about 60%. In contrast to this the improvement of AD is much better in the researched area than for the total Darmstadt.

**Figure 10**

The observed speeds may give an explanation for the strange development in the researched areas. The evaluation of several observation points for the V85-speed indicates no change of the speeds for zone as well as for the surrounding major roads, the decreases can be neglected. The same speed-level in the after-period could be an explanation for the poor traffic safety development in the 30 kph-zone. The 30 kph-zone may give an impression of a good safety for all road users but the speed level does not fit to it.
5 Conclusions

The conclusions have to be refer to the starting question and the working hypotheses. First of all the three working hypotheses are falsified totally. The speed level is in the before and after period nearly the same. The accident density and the severity on the surrounding major roads changed more positively than in the 30 kph-zone and especially for the category accident with fatalities and casualties. The positive development in the surrounding major roads was totally compensated by the negative effects in the 30 kph-zone. The following conclusions can be drawn: Intersections with link have to be designed carefully, especially the exit of the 30 kph-zone. Decreasing of the speed-level in the 30 kph-zone and enforcement of low speeds are of a high priority, though structural changes give an impression that all necessary measures have been carried out. The implementation of 30 kph-zone can give an dangerous feeling that everything for traffic safety was realised. Traffic safety of the surrounding major roads and their improvement have to be regarded despite the focus on the 30 kph-zone.

The future for a still increasing traffic safety can be described e.g. as following. In one of the researched areas a roundabout was built in the 30 kph-zone to minimise the conflict points and to improve the traffic flow. The roundabout has reduced effectively the speed in the approaches of the intersection. One of surrounding major roads was reconstructed in
connection with a speed limit of 30 kph to get a better traffic flow of all road users. Separated bicycle paths and crossing islands were built. This measure is very effective, has a good acceptance and fits very well to the environment.

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Safety assessment by road user – result from questioning 100 motorists on the A45 in Germany
Thorstenn Kathmann

„Traffic of life“ – The human factor in traffic safety programmes
Pieter Venter

Road safety programme in Tanzania
B K Steinset

An approach to create support for speed reduction
Jeroen Kempen
Safety Assessment by the Road User - Results from Questioning 1000 Motorists on the A45 in Germany

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1 Introduction

During recent years it has become recognized in Germany that in a service society the consumer has a center stage position. This development continues on the transport sector where the working authorities recognize that they offer a service to the motorists and that they have to contribute to an overall improvement of the traffic situation.

For a typical German highway there are a variety of authorities that have to work hand in hand. Quite often it can be seen that communication between them is not what it should be and that the demands and needs of the other authorities are not widely known. This is a point where there is need for improvement because only when all authorities work together can the resources be efficiently used and an "optimal" product can be provided for the motorists i.e. a safe and efficient highway.

Against this background the motorway police (Autobahnpolizeiinspektion Süd) in Hagen, Germany, developed the idea of a Public Partnership (PP) for the A45. In this partnership all the different parties responsible for safety or service for motorists on the motorway A45 were included. The partners in the PP consisted of the following (figure 1):

- Motorway Police (Autobahnpolizeiinspektion Süd), Hagen
- Breakdown Service of the German Automobile Association (ADAC), Dortmund
- Department of Goods Transport (Bundesamt für Güterverkehr), Münster
- Customs Investigation Department (Zollfahndungsamt), Münster, Abt. Dortmund
- Fire & Rescue Service (Berufsfeuerwehr), Hagen
- Petrol Station (Tankanlage), Siegerland-Ost / Siegerland-West
- Catering Franchise Holder (Rastanlage), Siegerland-Ost / Siegerland-West
- Highway Agency (Westfälisches Autobahnamt), Hamm
- Road Building Office (Westfälisches Straßenbauamt), Bochum
- Highway Surveillance Centre (Autobahnmeisterei), Hagen / Lüdenscheid / Freudenberg / Dortmund

Figure 1: The partners of the public partnership A45 (Foto: Autobahnpolizei Arnsberg)
The first meeting of the PP was held in July 1998 and the public partnership was formed. It was agreed to meet regularly in working groups who would report to the PP. The PP agreed to carry out a survey of the users wishes to identify problem areas in the way the various institutions in the PP provided their services. This survey was agreed to be in the form of questioning of motorists using the A45. The Institute for Road and Traffic Engineering of the University of Technology Aachen (RWTH Aachen) were asked to design and supervise the questioning.

2 The questionnaire

In compiling the questionnaire it had to be borne in mind that the interests of all partners had to be represented but that the questionnaire should not be too long in order to achieve a high acceptance rate. The German recommendations for traffic surveys /1/ express this as follows:

"Every questionnaire is a compromise between the load bearing capacity of the interviewee and the information requirements of the interviewer." /1/

In the initial discussions the interests of all partners were collected and drafts of the questionnaire were developed. This was done in close cooperation between the Institute for Road and Traffic Engineering and the motorway police. Additionally care was taken that the questions were formulated in a neutral way and that the questionnaire had a sound psychological structure.

To achieve a statistically significant result it was decided to question 1000 motorists. The personal interview was chosen in order to reach this aim in a relatively short time and with justifiable effort (and cost). Pre-tests showed that the questioning with the final version of the questionnaire took 6 minutes.

The questionnaire itself was divided in 3 parts. The general layout of the questionnaire was as follows:

<table>
<thead>
<tr>
<th>Part 1: General Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>name of interviewer</td>
</tr>
<tr>
<td>place of questioning</td>
</tr>
<tr>
<td>age and sex of the interviewee</td>
</tr>
<tr>
<td>vehicle type</td>
</tr>
<tr>
<td>reason for trip(business or private)</td>
</tr>
<tr>
<td>frequency of trips on the A45</td>
</tr>
<tr>
<td>distance of trip on the A45</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 2: Safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 questions on safety on highway and at service areas.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 3: Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Questions about “service” such as travel information, road works management, general.</td>
</tr>
</tbody>
</table>
3 The survey

For the survey a stretch of the A45 motorway was chosen as this was part of the areas of responsibility of all partners. The location is shown in figure 2.

The chosen stretch of the A45 has a length of around 100 km and consisted in the most parts of 5 lanes (3 in the direction of Dortmund) with an Annual Average Daily Traffic flow of between 50,000 and 70,000 vehicles per day. The percentage of HGV's is about 20 %.

On the two sections of A45 between the junctions for Lüdenscheid and Meinerzhagen and the junction for Hagen-Süd and the intersection Westhofen the A45 traffic control system has been installed which, depending on the traffic volume, incidents and especially in dangerous weather conditions, varies the mandatory speed limit.

8 officers of the motorway police volunteered to execute the questioning in civilian clothes.

Various days of the week, including weekends, were chosen for the surveys in an effort to gather opinions from all the users of the services. The questioning itself was conducted in November and December 1998. During the morning peaks commuter car parks were chosen to reach the typical commuters. Car parks were chosen at:

- Dortmund Eichlinghofen
- Hagen Süd
- AS Freudenberg

The questioning of the commuters was undertaken while they waited for their lift. The only problem that occurred was that after the first days nearly all commuters using the car parks had been questioned so that further questionings were not possible.

Main places for the remaining questioning were:

- Service area (Tank- und Rastanlage) Siegerland-Ost
- Service area (Tank- und Rastanlage) Siegerland-West
- Service area (Tank- und Rastanlage) Sauerland-Ost
- Service area (Tank- und Rastanlage) Sauerland-West

All of these locations are shown in figure 2.
The survey was positively received by all of the motorists stopped for questioning. This response was probably helped by the media interest in the event. During the first days there was live coverage of the questioning from the German television service WDR. There was also a documentary programme on the German television of the "Big questioning on the A45". In the regional daily newspapers numerous articles were published as can be seen from the press cuttings in figure 3/10/.
A 45: Fahrer-In Drängler und Gaffer nerven

Polizei intervientiert Fahrer im A 45-Nachtverkehr

Umfrage unter Benutzer der "Sauerlandlinie" zu Beginn der Ordnungsphase

Witterung und die "anderer Fahrer" gefährdete Sicherheit

Autobahnpolizei startet Befragung

Sind Sie mit dem Stau zufrieden?

Autobahnpolizei startet Befragung

Polizei aus Hagen und Freudenberg wollen von Autofahrern wissen:

Ärgerlaus Baustellen: "Meistens wird da nicht gearbeitet"

ADAC: Fahrer-In Drängler und Gaffer Fährner

Einige Autobahnen werden als "Drängler" oder "Gaffer" bezeichnet, nach Angaben der ADAC. Die Autobahnpolizei intervientiert nun Fahrer im A 45-Nachtverkehr.

Studie zeigt, dass Witterung und andere Fahrer oft die Sicherheit beeinträchtigen. Die Autobahnpolizei startet eine Befragung.

Die Zufriedenheit mit dem Stau wird von der Autobahnpolizei untersucht.

Die Autobahnpolizei in Hagen und Freudenberg möchte von Autofahrern wissen, ob "Ärgerlaus Baustellen" immer arbeiten.

Von Velmer Römer, ADAC, wird darauf hingewiesen, dass "meistens" an Baustellen gearbeitet wird und "stets" eine Überprüfung der Arbeitserfolge durchgeführt wird.

Parallel to the questioning the Institute for Road and Traffic Engineering developed a computer routine to input the data and do a statistical analysis. The data input, from the 1000 completed questionnaires, was undertaken by volunteers from the motorway police.

This task was started immediately after the questioning as it was the intended to present the results of the questioning quickly so as to maintain and build on the interest shown.
4 Results

In the following text the results to each question are presented in detail. Generally the results presented here reflect the opinion of all respondents, but in a few cases was it considered to be important to differentiate between different groups of motorists i.e. car drivers/HGV drivers or men/women.

As a personal interview was chosen as means of questioning it was possible to reduce misunderstanding in the responses given and therefore all 1000 questionnaires could be included in the analysis.

Part 1: General Information

Figure 4 shows the characteristics of the motorists questioned (sex, age, types of vehicle, etc.).

![Graph showing characteristics of motorists](image)

**Key**
- m/f: sex
- b.25/b.50/a.50: means of travel
- car/camper/mbike/HGV/bus: reason for trip
- buss./pr.: frequency of trips on A45
- v. offt/oft/seldom: distance of trip on A45
- below 25 years/25-50 years/above 50 years: age
- sex/male/female
- car/camper/mbike/HGV/bus: business/private
- below 25 km/25-50 km/above 50 km: distance of trip on A45

**Figure 4:** Analysis of part 1

The key points from part 1 can be seen to be:

- most interviewees were male (79%)
- most interviewees were aged 25-50 (69%), followed by over 50’s (23%) and under 25’s (11%)
- 71% of interviewees used cars
- 25% of interviewees used HGV’s
- 3% of interviewees used other modes of travel
the frequency of traveling on the A45 was equally distributed between very often, often and seldom
most motorists traveled more than 50 km on this trip

The final key point noted above was probably a factor of the locations chosen for questioning, i.e. car parks and service areas.

**Part 2: Safety**
The key points from part 2 were found to be

- 37% of motorists were concerned that their safety was threatened in using the A45 (and 63% were not)

These motorists with concerns for safety (n=370) were asked to give reasons for their concerns. These are presented in figure 5 and the key points were:

- 23%: weather conditions
- 20%: inconsiderate drivers
- 13%: road works and work sites
- 1%: HGV’s
- 10%: congestion

![Figure 5](image-url)

**Figure 5:** Overall view of the results to the question "Do you see your safety on the A45 endangered in a strong or frequent way? If yes, what is the reason?"

The next question "Have you experienced situations on the A45 in which your safety was directly endangered?" was used to get information about the actual safety situation on the
motorway. 42% of those questioned stated that they had already experienced such a situation. Figure 6 shows the evaluation of their answers. It must be noted that a relatively large quantity of answers fell into the category "Further remarks" (18%).

Figure 6: Overall view of the answers to the question "Have you experienced situations on the A45 in which your safety was directly endangered? If yes, what were those situations?"

Here the high percentage giving of "inconsiderate driving behaviour by other motorists" (38%) and "dangerous weather conditions" (34%) are especially striking. The answers which were given in the category "further remarks" are summarized in figure 7.

Figure 7: Overall view of the answers to the question "Have you experienced situations on the A45 in which your safety was directly endangered? If yes, what were those situations?", Answers in the category "Further remarks"
39% of all interviewees stated that they have experienced dangerous situations in which their safety was endangered by "inconsiderate driving behaviour of other motorists". Once again it can be seen that the interviewees not only felt their safety endangered, but had already experienced such situations. A similar distribution can be seen if the analysis is only done for HGV drivers. In the category "Further remarks" around 52% of respondents answered that they have experienced dangerous situations caused by inconsiderate driving behaviour of other motorists.

As well as gathering the opinions of the motorists it was also the aim of the survey to get to know more about how different measures can improve safety and how they are judged by the motorists. For this "High", "Medium" and "Low" were allowed as answers for the effectiveness. The results of the question "The following measures could reduce crime in service areas on the motorway A45. Please consider their effectiveness!" are shown in figure 8.

![Graph showing measures and their effectiveness]

**Figure 8:** Overall view of the answers to the question "The following measures could improve the safety for criminal acts in service areas on the motorway A45. Please consider their effectiveness!"

Concerning the answers "Raised police presence in service areas", "Improved lighting situation in service areas", "Reservation of women's parking" and "Installation of emergency call points" the tendency is equally positive. 70% of all interviewees consider the effectiveness as "high". 54% also think that a "CCTV-surveillance system of the whole service area" would be effective. Quite the opposite can be detected concerning the "short routes between car park and petrol station/service station", where 40% of the interviewees consider the effectiveness of this measure as "low". It is also interesting to note the results of the effectiveness of "Private security companies". 51% assess that the effectiveness is "low", 27% as "medium" and only 22% as "high". This means that all the motorists
questioned judged the effectiveness of the police higher than that of private security companies. Furthermore it is interesting to note that with 79% of male motorists the effectiveness of reserved parking spaces for women was rated as "high" however women did not agree. 210 women were questioned and 73% had the opinion that the reservation of parking places for women has a "low" effectiveness. A reason for this clear rejection, which was confirmed in numerous talks with the highway police, was the fear that this type of reservation made it easier for criminals to target females.

The results to the last question in part 2 ("Safety") "With the following measures the traffic safety on the A45 could be improved. Please assess their effectiveness!" are shown in figure 9.

![Figure 9: Overall view of the answers to the question "With the following measures the traffic safety on the A45 could be improved. Please assess their effectiveness!"

Three measures were judged by the motorists to be especially effective. These were:

- Warning systems for traffic jams, fog, black ice, etc. (high: 89%)
- Actual traffic information broadcasted by the radio (high: 75%)
- Execution of road works in the night time (high: 64%)

Also a "raised traffic surveillance by the police" and "overtaking ban for HGV's" are considered to be highly effective. Nevertheless it is striking that the raised police presence in the service areas is thought to be effective (see figure 8) but that this is not also the case for the highway. It can be concluded that on the highway a close surveillance of the motorists own behaviour is not desired.
Part 3: Service

The following 6 questions were aimed at the "service" which is offered on the A45.

The first question concerned the main reasons for traffic jams on the A45 and the following answers were given:

- work sites/road maintenance works (38%)
- high traffic volume (34%)
- accidents (17%)
- Further remarks (12%)

Examination of the answers from those motorists who stated "Further remarks" shows that the main reason is (once again) the "inconsiderate driving behaviour of other motorists" (59%).

In connection with traffic problems motorists were asked to judge the frequency of the jams on the A45. The majority of the interviewees rated the frequency as reasonable (75%), 16% judged the frequency as unreasonable and 9% as low.

Nowadays a motorist has a multitude of means and methods to inform himself of the current traffic situation, either before or during the trip. Some of the partners in the PP are also information providers and were keen to know more about how their service is used. The results of the question "Which sources do you use for traffic information and how do you judge the quality of this information?" are shown in figure 10.

![Graph showing source and quality of traffic information]

**KEY**
- tr. broadc. serv. = traffic information broadcasting service
- priv. t. i. centers = private traffic information centers
- internet = traffic information in the internet
- autom. ass. = traffic information from the German automobile association (ADAC)
- daily press LWL = traffic information in the daily press from the regional transport department (LWL)
- cong. pred. intern. LWL = congestion prediction in the internet offered by the regional transport department

**Figure 10:** Overall view of the answers to the question "Which sources do you use for traffic information and how do you judge the quality of this information?"
Seeing the results it becomes quite clear that despite some new developments in the area of traffic information the traditional traffic broadcasting service is still No. 1 and that the quality of this service is rated between "good" and "medium". Concerning the other sources of traffic information three further major sources are seen to be used. These are private traffic information centers, the German Automobile Association (ADAC) and the information in the daily press from the regional transport department (Landschaftsverband Westfalen-Lippe (LWL)). But the rating by the motorists differ quite a lot. The service offered by the private information centers and the ADAC are mostly rated as "good", but the services offered by the LWL only get the marks "medium" to "bad".

During the analysis a further source of traffic information could be detected which was not obvious on first sight. Around 20% of the interviewees answered to the above question "Further remarks" and most of these (84%) gave the CB-radio as a source. A more rigorous analysis showed that 98% of the HGV drivers gather their information in this way. The remaining 2% of the HGV drivers get their information by "talking to each other".

The next question was concerned with the repair of road damage and the execution of these repair works (see figure 11).

![Figure 11](image)

**Figure 11:** Overall view of the answers to the question "For the repair of road damage and the execution of maintenance works the Westfälische Autobahnamt Hamm of the LWL is responsible together with the regional highway agencies. Please assess the following:"

The safety measures taken and the quality of the work are rated as "good". The opposite opinion is given concerning the "means of work and the professionalism". Here the majority of the interviewees rated with "medium" (31%). The worst result gets the "timing of the road works". 43% rate the timing as "medium", 36% as "bad" and only 15% as "good". This result corresponds with the opinion of the interviewees who acknowledge "road works at night time" as highly effective.

The question "Is the extent of the following services on the A45 adequate?" resulted in the following answers (fig. 12).
Figure 12: Overall view of the answers to the question "Is the extent of the following services on the A45 adequate?"

All in all there was quite a positive picture. In all cases the service provision was rated as adequate. Especially positive were:

- car parks \( (91\% \text{ yes}, 9\% \text{ no}) \)
- rest areas \( (88\% \text{ yes}, 12\% \text{ no}) \)
- petrol stations \( (89\% \text{ yes}, 11\% \text{ no}) \)
- service areas \( (89\% \text{ yes}, 11\% \text{ no}) \)
- emergency call points \( (88\% \text{ yes}, 12\% \text{ no}) \)

Not quite so clear is the difference between "yes" and "no" concerning the HGV parks (56% yes, 44% no), sanitary installations (65% yes, 35% no), police presence (62% yes, 38% no) and traffic information installations (67% yes, 33% no). In this area there seems to be some need for activity.

In the last question it was the aim to gather information about the condition of the different elements of the A45 (see figure 13).
Figure 13: Overall view of the answers to the question "How do you rate the condition of:

The positive result of the previous question were repeated. The condition of the "highway", "service areas", "petrol stations" and "sanitary installations" was mostly rated as "good". Only the condition of the "car parks" gets the rate "medium" (44%) from the majority of the interviewees.

5 Conclusions

The majority of questioning reported in this article was focused specifically on the A45 motorway in Germany therefore the results of the survey and the specific conclusions cannot be directly transferred to other motorways. However the large amount of data generated from the questioning shows a general opinion of the safety on motorways which may well be applicable to other motorways both in Germany and abroad.

The large amount of data collected in the survey allowed for a detailed analysis however the results of this analysis have been generalized for presentation in this article. The detailed analysis of the data differentiated according to gender, means of travel, age group and frequency of trips on the A45 and resulted in further clues for the discussions between the partners of the public partnership.

Altogether the results from the questioning showed that, at least for the A45, the partners are already working successfully together and therefore get good marks from the motorists for the services they offer. Nevertheless they will need to work together in future in a more focused way as in a service orientated environment the users expectations continually rise.

As a direct result following the questioning the partners introduced the following measures:

- The partners will continue to meet in working groups to address problems on the A45 directly and to solve them jointly.
- The police presence in service areas has been raised.
- The problems of insufficient HGV parking spaces, which can only be solved in the long term, is undergoing further study to establish just what is needed.
Whenever possible road works will be done in low flow situations.
Research into provisions and facilities to resolve other safety problems has been started.
A newsletter for motorists (called PP – up to date) is planned.

The Public Partnership has been successful in establishing how its services are received by the motorists and is now trying to put right the problems the survey has highlighted. The partners have a better understanding of each others needs, a focus point for addressing problems and for disseminating information and even for helping each other. Such as group must be a benefit to motorists using the A45 and it is recommended for other road agencies/areas not only in Germany.

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INTRODUCTION

Traffic safety authorities are well aware of the complexity of the persuasion task, which they face. Getting people to do what the authorities want them to do, i.e. adopt and maintain road behaviour that will contribute to their safety, is no easy task.

Unlike marketing campaigns for consumer products such as soap, which take people as they are and offer them what they desire, marketing campaigns for traffic safety are aimed at changing people. Marketers of consumer products rarely have to create non-existent needs. They study ongoing action and design a proposition which chosen targets will find attractive. The persuasive message is: “Carry on, but choose our proposition.”

Traffic safety authorities usually have a different persuasion task. Instead of giving people what they want, the persuasive message is more likely to be: “Do not continue what you are doing because you like it, but please change because it is good for you and others – even if you don’t like it”.

The road users are furthermore liable to be punished if they do not change their road traffic habits, while the consumers of other marketed products are rewarded for their choice.

Traffic safety campaigns can only succeed if the developers keep in mind that marketing products and services are different to persuading people not to do something they like doing, e.g. speeding. To ignore this difference will result in an ineffective campaign.
THE TRAFFIC SAFETY CAMPAIGN AS A FORM OF INFORMAL EDUCATION

The influencing of traffic behaviour is an important prerequisite for the promotion of traffic safety. Measures taken to change road users' behaviour in traffic can either be direct or indirect. Indirectly the road user’s behaviour can be influenced by the technological improvement of vehicles or the road environment. Examples are seatbelts, air bags and sophisticated braking systems of vehicles and rumble strips and speed limits on roads.

Measures aimed directly at the road user include formal and non-formal education and training programmes, informal education programmes (such as campaigns) as well as law enforcement.

The traffic safety campaign must be seen as an educational medium through which traffic behaviour can be influenced positively as long as the enhancement of the road user’s knowledge, skill and cognition is included in the primary objectives.

ATTITUDE AND BEHAVIOURAL CHANGE

The term attitude refers to certain regularities of an individual’s feelings, thoughts, and predispositions to act toward some aspect of his environment. Feelings are often referred to as the affective component, thoughts as the cognitive component, and predispositions to act as the behavioural component.

There is a distinction of some importance between attitude and value systems. Attitudes are thought of as pertaining to a single object, even though that object may be an abstract one. Value systems, on the other hand, are orientations toward whole classes of objects. Individual attitudes are frequently organized into a value system. In a broader sense, an individual’s entire personality structure and hence his behaviour may be thought of as organized around a central value system comprised of many related attitudes.
An individual's value system will have a specific characteristic if his/her attitudes are consistent with each other, and if he/she behaves in accordance with his/her attitudes. It is accepted, though that a person does not necessarily behave in accordance with his/her verbally expressed attitudes. This inconsistency inevitably leads to dissonance. One of the commonest forms of choice made in everyday situations is commitment to one or two or more alternative actions, where commitment to one path requires giving alternative actions. Another form of commitment that creates dissonance requires a person to behave in a manner opposite to his attitudes. This type of situation is termed a forced-compliance situation, or the behaviour is referred to as attitude-discrepant behaviour. A person may be forced to comply in a manner that is in contrast with his/her attitude through reward threat or punishment.

The mass media campaign is an example of a method applied to influence a person to behave in a specific manner that is in accordance with his/her attitude or to change the attitude to comply with the required behaviour.
BEHAVIOURAL CHANGE THROUGH CAMPAIGNS

Behavioural change through persuasive communication takes place through a 12-step process (dependent variables). For an educational campaign to be effective, the people whom it is aimed at must go through the following steps:

- exposure to the message;
- pay attention to the message;
- be interested in the message;
- understand the contents of the message;
- have the necessary skill to perform the required behaviour;
- change attitude in accordance with the message;
- memorise the message;
- recall information from memory;
- decide to behave according to the recalled information;
- behave according to decision;
- confirmation of appropriate behaviour;
- consolidation of behaviour.

A further five variables, which may have an influence on the process of behavioural change by increasing the persuasiveness of the message, are of importance:

- the source of the message;
- the message itself;
- the medium used to convey the message;
- the receiver of the message;
- the objective of the message.

A major pre-requisite for behavioural change through educational campaigns is that the target person pays attention to the message.
In principle mass media must have the greatest effect, but people tend to be selective and it must not be taken for granted that they are interested in the message or that they will pay attention to it.

The message must furthermore be clear and understandable. The receiver must be in no doubt about the essence of the message carried by the campaign.

All of the aforementioned concentrate on the message, which emphasizes the fact that in considering persuasion through communication, one’s attention is often focused on the communication itself. It is natural to think of the communication as the primary force for change. If the communication is effective, one thinks, the desired influence or persuasion will take place.

One problem that needs closer investigation though, concerns the relative merits of “emotional” versus “rational” appeals. Unfortunately the identification of a communication as having a rational or an emotional appeal is not always clear-cut. A rational appeal may arouse certain emotions; an emotional appeal may make a person think.

One type of emotional appeal is the “fear appeal”. In essence, all fear appeals “threaten” the individual with unfortunate consequences unless he/she follows the advice of the communicator. Thus, the terms threat appeal or fear appeal are commonly used to refer to them.

Research has shown that messages with a strong fear appeal produced a great amount of worry and little or no change, while messages with minimum fear appeal brought about major increase in conformity to accepted practices and no anxiety. There is also a suggestion that the strong fear appeal arouses strong emotion, but the individual reduces his/her anxiety by a denial mechanism. An alternative interpretation, however, is that the high-pressure tactics of the fear appeal are offensive and arouse resistance.
A MODEL FOR BEHAVIOURAL CHANGE

Kok (1985 as quoted by Rooijens, 1985: 61) designed a model that focuses on the individual process of behavioural change. His model contains the following important steps:

<table>
<thead>
<tr>
<th>ATTENTION</th>
<th>SELECTIVITY</th>
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<tbody>
<tr>
<td>INSIGHT</td>
<td>COMPREHENSION</td>
</tr>
<tr>
<td>CHANGE OF ATTITUDE</td>
<td>ADVANTAGES AND DISADVANTAGES</td>
</tr>
<tr>
<td>CHANGE OF ATTENTION</td>
<td>SOCIAL NORMS</td>
</tr>
<tr>
<td>BEHAVIOURAL CHANGE</td>
<td>IM/POSSIBILITY</td>
</tr>
<tr>
<td>CONSOLIDATION OF BEHAVIOUR</td>
<td>FEEDBACK, HABITS</td>
</tr>
</tbody>
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According to Rooijers (1985: 62) an important link in the process of behavioural change is the comparison of advantages and disadvantages of the recommended new behaviour. The biggest problem traffic safety educators are confronted with is the fact that to most road users negative consequences of unsafe traffic behaviour seem to be a very unlikely probability, whilst positive consequences are often experienced directly.

THE EFFECTIVENESS OF MASS COMMUNICATION

There seems little doubt that the mass media, through providing repeated exposure to a commercial product, can acquaint large numbers of people with it. Whether or not such exposure to a product leads to acceptance of it depends upon the person’s attitude towards the use of the product, the degree to which his/her habits are already established, and the number of competing communications.
Where communications run counter to important attitudes, however, quite a different result may be expected. Mass communications that attempt to bring about marked changes in attitude are unlikely to succeed. But communications that capitalize on attitudes and motives already existing in the population, and that produce facts leading to an easily available course of action serving these attitudes and motives, may be quite effective.

One may conclude that intensive exposure is usually effective in acquainting a person with some topic or product, but whether or not he/she takes any action on it depends upon several factors:

- the strength of his/her attitudes pertaining to the issue
- whether his/her attitudes are conducive to or opposed to the action, and
- whether action is clearly outlined in the communication.

**FACTORS CONTRIBUTING TOWARDS A SUCCESSFUL EDUCATION CAMPAIGN**

According to Rooijers (1986: 65) the following factors should receive attention in the designing and implementation of an education campaign:

- A reward system can contribute to the effectiveness of an education campaign. A punishment system’s contribution will be less effective than that of a reward strategy. A reward aimed at future behaviour has a greater effect than an unexpected reward for past behaviour.

- A national campaign will be the most effective when it is divided into smaller campaigns, which are aimed more directly at the local population.

- In an education campaign a combination of mass media must be implemented.

- Each education campaign must be preceded by an investigation to determine the cognizance, convictions and values of the target group.
A variety of “messengers” must be used to convey the uniform educational message. Especially, during campaigns running over a long period a variety of messengers will prevent the target group from becoming too used to and bored with the message.

An education campaign is most effective when it conveys the message that the majority of the target group has already conformed.

CONCEPT OF THE LIFE CYCLE

Every individual has a lifeline, beginning with conception and ending with death. On this lifeline, certain ages are noted for special age-related events in our society. Obviously, the end points are set by biological and physiological variables: and biological growth plays an initially central but decreasingly important role as we scan the lifeline from conception to birth, from birth through puberty, and from puberty through middle age, and so on. But what variables determine the significance of events on the lifeline that are biological? What do these milestones represent?

One useful analogy is to think of the lifeline as a representation of a journey with a number of interesting places and crucial junctions along the way. Some years ago when travel was slower, roads were commonly marked with milestones or mileposts to mark off each mile traveled. These milestones were important because the traveler was progressing toward a goal through time, and progress was measured by the number of miles traveled in a unit of time. Humans tend to mark off their progress through their life cycle in a very similar way. The notion of milestones in human development is an appropriate concept, because when we think of the life cycle we mark it off with developmental milestones and, in fact, often celebrate these milestones (such as graduation, marriage, or retirement).
THE “TRAFFIC OF LIFE” TRAFFIC SAFETY PROGRAMME

The CSIR Transportek and NALEDI adopted the life cycle concept to form the basis of the “Traffic of Life” traffic safety education programme. As a mass media project the campaign is designed on the requirements for effective mass media communication identified by Rooijers.

The main objective of the project is to design and facilitate a comprehensive, integrated safety programme aimed at different stages of development in one’s life – imbued with customized messages for each target group. The focus of the programme is on the projection of an image of “a journey through life”.

In the Traffic of Life programme traffic safety problems are approached from a positive influencing point of view by reinforcing the positive nature of the journey through life. The idea is therefore to celebrate the value of life.

The aims of the alternative integrated and comprehensive package is to:

- Foster greater regard for life
- Engender a culture of responsible road usage within South Africa
- Increase community and public awareness on issues such as using seatbelts, visibility, pedestrian safety, alcohol and drug abuse, and the dangers and consequences of speed
- Make use of our rich cultural heritage for purposes of promoting traffic safety.

The Traffic of Life project is based on the concept of a South African family and their journey through life. Throughout their lives the different family members reach specific “milestones” which are celebrated in ways typical of their beliefs and culture. The importance of the value of one’s own and others’ lives and the importance of safe behaviour in traffic is emphasized throughout.
During each of the stages of the life cycle a variety of safety aspects can be emphasized, e.g.:

- pedestrian safety,
- speeding
- alcohol and drug abuse
- visibility
- road worthiness
- cyclist safety
- child restraints
- seatbelts, etc.

The value of life and the joy of celebrating the various milestones can be central to each of the themes.

CONCLUSION

It has been stated previously that mass media communications are more likely to have an effect on an individual when the message conveyed capitalize on
attitudes and motives already existing in the population and produce facts leading to an easily available course of action serving these attitudes and motives. Cognitive consistency paves the way for accepting demands on changes in attitudes because there is no tension between two or more inconsistent thoughts. In general the road users in the country are people who value their own and other people’s lives. People want to grow old and celebrate the various life stages and achievements. Positive traffic safety messages focusing on the value of life should therefore keep the communicators’ viewpoints and the road users’ understanding of the value of life in agreement with each other.

The “Traffic of Life” project wants to capitalize on this attitude which already exists by bringing messages which will enhance an attitude in such a way that road users, parents, teachers, politicians, etc. will become part of a group of people who can serve as an agent of change.

This project with its positive messages can make a contribution towards changing attitudes if it can succeed in making road users feel that by committing themselves to a change and by making a decision to change they will bring about effective attitude shifts.
BIBLIOGRAPHY


Road Safety Programme in Tanzania

Co-operation between Ministry of Works (MoW), Tanzania and the Norwegian Public Roads Administration (NPRA), Norway

Author: Chief Engineer B. K. Steinset, Norwegian Public Roads Administration.  
Co-authors: Senior Engineer C.W. Chiduo, Road Safety Unit, MOW, Tanzania

1.1.1.1 Background

The Norwegian agency for development co-operation, NORAD, has been engaged in road projects in Tanzania for more than thirty years. Previously the aid largely has been in the form of Norwegian Experts working on specific projects usually for a period of two to four years. In the beginning of the 1990’s there was a change in the official policy of NORAD. The new NORAD policy involves transferring of more responsibility for the projects to the developing countries. As a part of this policy NORAD involved NPRA in institutional co-operation with sister institutions in developing countries as Tanzania, Botswana and Zambia.

1.1.1.2 Some information about roads and traffic in Tanzania

Tanzania covers an area of 945 000 km² and is the largest country in East Africa with a population of about 33 mill. The roads are playing a crucial role in the economic activity and development of Tanzania. More than 70 percent of the freight movement in Tanzania is by roads. Roads transport over 75 % of all agricultural products. 75 % of the population live in rural areas where it is accessible only by roads. The total length of the road network is about 88 000 km. Only one third of trunk roads and 5 percent of regional roads are paved.

Average Daily Traffic (ADT) on the roads in Tanzania is relatively light. On paved roads it is generally from 200 to 500 vehicles per day except for some few roads near Dar es Salaam and Arusha that carry about 1,000-1,500 vehicles per day. On regional roads it is usually below 50 vehicles per day.

For Tanzania the estimates of the vehicle fleet are about 250 000 vehicles. Pickups and four-wheel drive vehicles comprises about 30-50 %, commercial vehicles about 30-40 % and private cars less than 10 of the traffic volume.

The magnitude and nature of the road safety problem in Tanzania is very alarming. In 1997, 1 625 were killed in road traffic accidents in Tanzania. This gives a rate of killed per 10 000 vehicle of 60 in Tanzania. This means that the risk of been killed per vehicle is 40 times higher in Tanzania than for instance in Norway. It is estimated that in 1997 Tanzania lost at least 20 billion Tanzanian shillings (US $ 25 million) through road accidents.

1.1.1.3 The mode of co-operation

A formal agreement on institutional co-operation within Road Safety and Axle Load Control was signed between Ministry of Works (MoW) and NPRA in 1993. The advisory support from NPRA has been concentrated on:
Establishing of a Road Safety Unit (RSU) within MoW and strengthening of the unit
A National Road Safety Programme Document
Accident Recording and Analysing System (MAAP-five)
Traffic Engineering and Road Design
Vehicle Safety
Axle Load Control

The programme has also included some financial support and minor NPRA-advisory within the fields of Drivers Training and Licensing, Road Safety Education for Primary and secondary Schools and Information. NORAD funds the co-operation.

Four advisors from NPRA, one external consultant from Norway and one from Great Britain (TRL) have been involved in the co-operation. The co-operation has been based on 1-2 visits of 3-4 weeks per year from the NPRA-Advisors to Tanzania, support from Norway and visits from MoW to Norway. A total of about 5.5 man-years has been spent on the co-operation from NPRA in the period 1993-99 (7 years). This also include co-ordination, programme preparation, administration etc. at International Division within NPRA. About a third of the support has been used for the Axle Load Control component. NPRA has also made a video about the co-operation.

For the whole 4-year period 1998-2001 the approved contribution from NORAD is 5 mill. NOK (0,625 mill US$). About 50 % covers the NPRA activities and 50 % is contribution to local activities and local consultants.

Achievement

Establishing and strengthening of a Road Safety Unit (RSU) within MoW

The Road Safety Unit (RSU) was established in 1992 and is headed by a Chief Engineer reporting to the Permanent Secretary of MoW.

The RSU is a small unit staffed by 6 engineers and 1 technician in addition to the Chief Engineer. The unit working with:
- Traffic Engineering and Accident Recording and Analysing (one engineer)
- Vehicle Safety (one engineer)
- Drivers Training and Licensing, Road Safety Education and Information (one engineer)
- Planning and Programming, Road Safety Education and Information (one engineer)
- Axle Load Control (two engineers and one technician)

NPRA has supported the unit with training and advise on how to organise and carry out the different issues within Road Safety and Axle Load Control, programming, budgeting and co-ordination of the Road Safety work in Tanzania. Study trips have been carried out both to Norway and neighbouring countries in the SADC & EAC region. NPRA has also supported the unit on arranging, participation and preparing of papers for conferences etc.
1.1.2 National Road Safety Programme Document

In 1995-96 a comprehensive proposal for a National Road Safety Programme Document was worked out. The programme addresses the most important issues pertaining to road safety. The overall objectives of the National Road Safety Programme are the following:

- To establish a road safety organisation capable of managing a multi-sectorial integrated approach to the road safety problem.
- To improve the quality of life in Tanzania by reducing the frequency of road accidents and minimising their consequences.
- To prevent undue damage to road pavements through stringent vehicle and axle load control

Among the proposals in the Programme are:

- transfer of the secretariat of the National Road Safety Council from the Traffic Police to the MoW and a National Road Safety Agency to be established under MoW.
- transfer of the responsibility for drivers training and testing from the Traffic Police to the MoW
- MoW to be responsible for the mandatory vehicle inspection on regular basis

Status of Implementation

A Cabinet paper on the proposed National Road Safety Programme was submitted to the Cabinet Secretariat for consideration in March 1998.

The Traffic Police and the Ministry of Home Affairs seem not to agree on these proposals, particularly the proposal for MoW to have the responsibility for the mandatory vehicle inspection on regular basis. The Cabinet Secretariat has therefore requested MoW to iron out the disagreement and obtain consensus. It seems to be difficult to obtain consensus on these issues. This situation is not unknown also in Norway.

However, we consider the document to be a good basis for future work. The document has also formed the basis for the Road Safety activities in the institutional co-operation between NPRA and MoW in the Road Sector Programme for FY 1997/98 - 2000/01. NORAD approved this programme in February 1998.

Accident Recording and Analysing System (MAAP-five)

To provide reliable data for accident analysis, an efficient accident recording and analysis system is required.

Status of implementation

In 1994 a new accident recording form was agreed upon. The form had to be tailor-made for Tanzania conditions and suitable for developed Micocomputer Accident Analysis Package version 5 (MAAP-five) developed by the Overseas Unit at the Transport Research Laboratory (TRL) in England. Short courses on how to use the forms were held for Traffic Police staff.
Computers for accident recording and analysis have been supplied to RSU, Traffic Police HQ and the 8 regions of Dar Es Salaam, Coast, Morogoro, Mbeya, Tanga, Iringa, Arusha and Dodoma. Training has been conducted both in basic computer knowledge and Microcomputer Accident recording and Analysis Package (MAAP-five). A total of about 100 officials mainly from the Traffic Police and MoW have been trained.

All road accidents in Dar es Salaam after 1 January 1995 have been registered on new forms and entered in the MAAP-five system. Accident recording into computers is also progressing well in Mbeya, Tanga, Coast and Morogoro regions.

For Arusha, Iringa and Dodoma the recording of data has just started by filling the accident recording forms. The computers have been procured and installed and some training has been conducted.

Traffic Engineering and Road Design

Activities under this sub-component is analysing blackspots; planning and implementation of countermeasures; develop Traffic Management and Engineering Manual; participate in developing a Road Design Manual including road safety measures; develop and implement a system for Road Safety Audit; and develop guidelines for traffic management / road safety teams in city, municipal and town councils.

Traffic planning, engineering and management especially in urban centres should be done with emphasis on road safety consideration. Training in this aspect is recommended for MoW and City/Municipal engineers. Traffic Management Sections should be created in Municipal Engineering Departments and be equipped to address safety issues.

Status of Implementations

Accident Analysis have been carried out and countermeasures proposed for the worst blackspot in Dar es Salaam and some of the other cities/towns. Accident Analysis and Road Safety Audit have also been carried out for some short sections of the road-network and countermeasures proposed and implemented i.e. speed devices on the TanZam Highway through Mikumi National Park.

However, this component is still at an initial phase and has to more focused in the future. Proposals on a road safety audit system for Tanzania have been prepared and auditing carried out for some selected roads and projects.

For FY 1999/2000 it is planned to engage a local consultant to prepare a more comprehensive Road Safety Audit System for Tanzania. A term of Reference for this consultancy has been worked out. This work has reached the tendering stage where the firms concerned have been asked to submit their bids.

Vehicle Licensing and Inspection

Faulty vehicles are the second largest contributing factor to the accident occurrence in Tanzania.
Today, Tanzania has no valid technical standards for vehicles. The vehicle inspection is only carried out for commercial vehicles when they are licensed. This vehicle inspection is carried out on the basis of the manufacture’s specifications manual.

All vehicles driving on the roads should be tested for roadworthiness. It is proposed that two types of inspection shall be carried out:

- Mandatory vehicle inspection by MoW on a regular basis
- Road side vehicle inspection by the Traffic Police

**Status of Implementation**

A Vehicle Safety Programme was prepared by RSU in 1998. Drafts on Vehicle Inspection Regulations and Vehicle Inspection Standards/Manual have been worked out.

Training on Vehicle Inspection tutors in Zimbabwe has been given for Traffic Police and the National Institute of Transport (NIT). Short courses in Vehicle Inspection have been arranged at NIT for the Traffic Police Vehicle Inspectors.

NPRA have given some training to in training the Vehicle Inspectors at the Traffic Police on roadside control. A roadside control of 43 heavy-duty vehicles, 20 light duty vehicles and 22 busses in April this year showed:

- 65% of the vehicles had faulty brakes
- 50% had lighting faults
- 50% had poor tyres
- 60% had faults in their suspensions
- 50% had faults on the steering system (60% of the busses)
- 60% of the vehicles did not carry a warning triangle
- 30% of the drives did not carry a drivers licence

From October 1999 a report for development of a Motor Vehicle Inspection system have been prepared by Bureau For Industrial Co-operation at the University of Dar es Salaam. This report include:

I. Motor Vehicle Inspection Act
   - Motor Vehicle Regulations
   - Vehicle Test station
   - Vehicle Inspector’s Handbook

National Institute of Transport (NIT) has also prepared a draft Vehicle Inspectors Training Manual.

The vehicle inspection is proposed to be carried out by specialised depots or stations classified into two categories/grades (one for testing all classes of vehicles and one for light vehicles only). These stations may be owned by private companies or by public institutions. In both cases, the stations shall be licensed and gazetted. The appointment of stations is proposed to be based on tender system. The stations shall be annually evaluated. Qualified vehicle inspectors who will have to be assessed and licensed shall carry out the vehicle inspection.
All vehicles are proposed to have a valid certificate of fitness before being allowed to ply on any roads in Tanzania.

NPRA has also assisted RSU in preparing Terms of Reference for establishment of a Computerised Central Motor Vehicle Database in Tanzania. This project is funded by SIDA.

Axle Load Control

The percentage of overloaded trucks on trunk roads is expected to be less than 10% after implementation of the Axle Load Control Programme.

Status of Implementations

All weighbridges have been visited and training on how to carry out the controls has been conducted.

Standard specifications both for mobile and fixed weighbridges have been worked out.

Nine mobile weighbridges have been procured and distributed to the RE’s (Shinyanga, Arusha, Kilimanjaro, Tanga, Mara, Morogoro, Iringa, Mbeya and Dar es Salaam).

A comprehensive draft Manual for Weighbridge Operators has been worked out. The intention of the manual is to provide the weighbridge staff (weighbridge-operators and the police) with an explanation in simple terms of the rules and regulations regarding the use of haulage vehicles on public roads in Tanzania. Furthermore it intended to assist in the understanding of the weighbridge organisation in Tanzania and the technical features showing supervision and maintenance procedures for the various types of weighbridges. The manual will also be useful for hauliers and automobile dealers in Tanzania.

A draft Amendment to the Road Traffic Act and Regulations regarding vehicle axle load control was finalised and submitted to the Minister for Home Affairs in October 1999. The Amendments have been approved and will soon be gazetted. The Manual for Weighbridge Operators will then be finalised.

An axle load control programme has been worked out including the following components:
• Review legislation and give statutory power to the staff
• Give professional training to the staff,
• Fighting corruption practices,
• Establishment of a national database on overload control,
• Improvement of the weighbridge utility (capital investment)
• Review of weighbridge locations for increased utilisation and efficiency
• Transfer of responsibility after establishment of a National Roads Agency
• Study of a parastatal or private sector operation.

In 1998/99 the Central Materials Laboratory assisted by RSU carried out a comprehensive axle load survey. In general 20-30% of the axles of the buses and goods vehicles are loaded above the legal limit of 10 tons and about 3% above 14 tons.

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Author: B.K. Steinset, Norwegian Public Roads Administration
Driver Training and Licensing

A new driver training system at registered driving schools which will require classroom instruction and the passing of a written standard examination before issuance of a learner licence is proposed.

Status of Implementation

The National Institute of Transport (NIT) has produced for RSU:
- a draft Learner Driver Manual
- a draft Tanzanian Highway Code. The draft is based on the SATCC-standards.

Some small preparations have also been carried out for a Tanzanian Drivers Instructor Manual, development of standards for driving schools and standards for driver testing/examination and licensing.

1.1.3 Enforcement

The Traffic Police is dealing with all enforcement issues. Financial support from the road safety programme for development of a Traffic Police Handbook (field book) has been indicated.

1.1.4 Education

It was planned to prepare a curriculum and to establish education in road safety in Primary Schools, Secondary Schools and Teacher Training Colleges.

Status of Implementation

In 1999 the Tanzanian Institute of Education has produced (both in Swahili and English) road safety education syllabus for primary and secondary schools, for diploma in education course (teacher training course) and modules for primary and secondary schools.

These documents have formed the basis for a pilot project on road safety education in primary and secondary schools in the Easter zone comprising of Dar es Salaam, Coast and Morogoro regions. The project started in January 2000 and evaluation of progress will be done in August 2000.

1.1.5 Information

The National Road Safety Week

The National Road Safety Week organised by the National Road Safety Council (NRSC), has been arrange for many years, normally in September. Places for the arrangement has shifted around the country. During the week, competition is held within singing, rhymes and drawing/painting are arranged involving primary school children.

In 1998 NRSC also organised the First National Road Safety Seminar whereby different papers on road safety were presented.
Weekly radio programme

A weekly radio programme of 15 minutes on road safety has been aired for some years. The RSU is planning the programme together with Radio Tanzania staff. Some of the contents of the programme are also published in newspaper articles. It is planned to start TV programmes from September 2000.

1.1.6 Some other constrains during the co-operation

From 1994 to 1998 no funds from NORAD for local activities where released due to lack of audit reports from MoW. Since many of the activities within the Road Safety and Axle Load Programme were based on local activities this has caused serious delays in the implementation of the planned activities. Also funds from IDA for equipment and civil works had been suspended. Work-plan and budgets had to be revised several times. For a period, all activities from NPRA were stopped.

During the period of co-operation the heads of the RSU (chief engineers) have been replaced four times (in 1993, 1996, 1997 and 1999/2000). Also among the RSU engineers there have been many changes. This has caused delay in the programme implementation.

1.1.6.1 Programme Review

The Norwegian Institute of Transport Economics (TØI) reviewed the whole programme in January/February 2000. They recommend the support to continue. They advice the Road Safety and Axle Load Control to be regarded as two separate field of activity. Axle Load Control is a road maintenance activity. Most of the efforts within Road Safety have been preparatory work. A clearer priority between activities are recommended. They recommend first priority within Road Safety should be given to:

a) Implementation of Road Accident Countermeasures
b) Programmes and Legislative Amendments

Their main recommendations for the road safety activity are:

Effective road safety measures such as traffic engineering and enforcement combined with information campaigns should be implemented as pilot projects. The result of these projects should be communicated effectively to the public at large and to decision-makers.

1.1.7 Accidents in Tanzania

In 1999, 1612 persons were killed in Traffic accidents on the Tanzania mainland. The frequency of road accidents increased rapidly up to 1997 – but seems to have been quite stable for the last two years. The increase of accidents was particularly rapid after 1990. Up to 1990 the number of accidents has roughly increased in proportion to the increase of vehicles on the road, but seems since to grow more strongly than the number of vehicles, i.e. the risk factor has increased. The risk of being killed in a traffic accident in Tanzania compared to the number of vehicles on the road is 30 - 40 times higher than USA and many countries of Europe.
Road accidents constitute a serious health problem in Tanzania. About 5 percent of deaths occurring in hospitals are reportedly caused by road accidents. Although it is difficult or unacceptable to give a monetary value to human life, an estimation of the loss due to road accidents has been quantified. The cost of a traffic accident can be treated as a sum of all resource costs (i.e., vehicle and property damage, medical, administration and legal costs) and the discounted value of deceased and disabled victims' future output.

The estimated costs of all road traffic accidents in Tanzania amounted to at least 11 billion shillings for the year 1994 or 1.25% of the GDP. The actual costs are thus likely to be in the range 15 - 20 000 million TAS (25-30 million US $). In this calculation no value was added to reflect "grief, pain and suffering" of the victim and those who care for him or her.

Passengers and pedestrians together constitute 81 percent of traffic accident casualties for the whole period 1992-99. Forty-one percent of those killed were passengers, most of them in buses but also a lot on pick-ups and lorries carrying passengers. There are indications that the privately owned Dala-Dalas (mini-buses) are over-represented in road accidents. Thirty-seven percent of the killed were pedestrians, 13 percent were cyclist and 6 percent drivers.

The dominating age group in accidents in Tanzania is 25 to 40 years. Three out of four of those killed are male.

In the period 1990-94, private cars were involved in 45 percent of the accidents, heavy-duty vehicles in 17 percent, buses in 12 percent and pickups in 10 percent. According to police reports in the period 1992-99, reckless or dangerous driving was a contributory cause in more then 50 percent of accidents and vehicle defects in 15-20 percent.

About 35 % of all accidents and 15-20 % of all killed accidents occur in Dar es Salaam region. Sixty-five percent of the fatalities in Dar es Salaam were pedestrians and 22 percent passengers.

Enclosed find some accident figures for Tanzania.
Injured and killed in Road Traffic Accidents
Tanzania 1980-1999

Year
0 2 000 4 000 6 000 8 000 10 000 12 000 14 000 16 000

Accidents
Killed
Injured

Road Traffic Accident Risk
Tanzania 1980-99

Killed pr. 100.000 inhab.

- Drivers: 5%
- Pedestrians: 25%
- Cyclists: 10%
- MC: 4%
- Passengers: 56%

Deaths by Traffic Groups in Tanzania. 1992-98

- Drivers: 6%
- Pedestrians: 37%
- Cyclists: 13%
- MC: 3%
- Passengers: 41%

Graphs showing the distribution of injured and deceased by traffic groups in Tanzania from 1992 to 1999.
Accident causes considered by the Traffic Police
Tanzania 1993-98

Vehicle type involved in accidents.
Dar es Salaam 1998
Accidents by Collision type. Dar es Salaam 1998

All Casualty by Age
Dar es Salaam 1998

Author: B.K. Steinset, Norwegian Public Roads Administration
Fatal by Age
Dar es Salaam 1998

Accidents by month. Dar es Salaam 1998

Author: B.K. Steinset, Norwegian Public Roads Administration
All Casualties by Day
Dar es Salaam 1998

No of Casualties

Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday

All Casualties Monday-Friday by Time
Dar es Salaam 1998

No of Casualties

00-02
02-04
04-06
06-08
08-10
10-12
12-14
14-16
16-18
18-20
20-22
22-24

Time of Day
"An approach to create support for speed reduction",
Drs. Jeroen Kempen, Project Manager of
the Dutch Traffic Safety Association - 3VO.

Introduction
One of the most important causes of traffic danger is speeding. It is for this
reason that speed reduction continues to receive a lot of attention in traffic
safety policy. Speed limits are imposed, regular speed limit checks are carried
out by the police, there are billboards along the roadways and TV commercials
are made, all in an attempt to convince road users to moderate their speed.
Despite these measures it appears that driving too fast in the traffic is a
phenomenon, which is very difficult to influence. We believe that the problem
cannot be tackled by solving the symptoms. We need a preventive approach.
That is why we introduced in The Netherlands the concept of sustainable
safety. A concept, which is comparable with the Swedish “Vision Zero” approach.

Start-up programme on sustainable safety
In December 1997 central, provincial and local governments and water boards
signed an agreement. It was agreed to collectively draw up an action plan for the
longer term and to start in the coming 4 years with what is achievable in the
One of the agreements of the covenant is to realise an important expansion of
30 km per hour zones. It has been agreed in the covenant to realise a major
expansion of 30 km per hour zones within a period of 4 years. 50% of the roads
designated for this purpose (12,000 km) are to become 30 km zones by 2001.

The importance of expansion of 30 km zones
A rigorous expansion of 30 km per hour zones greatly benefits the traffic
safety and mobility of vulnerable road users. The safety for pedestrians,
cyclists, children and the elderly needs to be the main priority in the majority
of streets in built-up and this calls for low speed limits. The functions of playing
and walking in residential areas cannot be combined with speeds higher than 30 km per hour. If you do, you take the risk that accidents will happen. This is why many local municipalities have had to make submissions to the central government for subsidies.

**Subsidy arrangements for Sustainable Safety**
In order to stimulate the countermeasures outlined in the start-up programme, central government has established a subsidy arrangement. The total implementation costs for this were estimated at around 400 million Dutch guilders (= 182 million EURO). Central government provides half of the funding and the remaining partners contribute the other 200 million Dutch guilders (= 91 million EURO).

To be eligible for subsidy, local road authorities have had to submit overall plans by December 1998 and to further elaborate these plans during the course of 1999. To actually receive the subsidy, the 30 km zone projects must be realised before 2002.

**Societal support for speed reduction**
The process of making submissions by the local municipalities could be stimulated by allowing residents to actively participate by applying at their local councils for more 30 km zones in their neighbourhood. An important part of this is that councils develop the plans in dialogue with residents. This also helps raise the public's acceptance of speed controlling measures.

It is precisely these two aspects of public participation (mobilisation and activation, as well as the creation of a basis of support and acceptance) which have enabled The Dutch Traffic Safety Association – 3VO to develop concrete plans.

These plans are two - fold. On the one hand we have the public campaign "*30 maakt je buurt weer prettig*" ("30 km zones in front of your own home") and on the other hand, a methodology for interactive policy forming. In the framework of this presentation I shall now elaborate on the public campaign.

**Public campaign "30 km zones in front of your own home"**
This campaign is associated with the start-up programme Sustainable Safety. It was a follow up to the anti-speeding campaign "Minder snel - dank u wel" ("Please slow down - Thank you").

The aim of the "30 km zone" campaign was three - fold.
1. The expansion of the number of 30 km zones, supported by a communicative approach.
2. The stimulation of residents to take action themselves by asking local councils for 30 km zones.
3. To create a supportive basis among residents and the public for the increasing amount of speed reducing measures that are being introduced for the improvement of safety and the quality of life in the neighbourhood.

**Phase 1 (May 1998)**
The campaign consisted of a TV-spot, a radio-spot, an internet site (www.3vo.nl), articles (advertisements) in house to house papers and posters. The posters are placed along the road-sides as well as in schools and community centres. In the commercials and house to house papers etc. residents have been called upon to make contact with their own local councils if they want to participate in the setting up of 30 km zones in their neighbourhood.

All of the relevant local council authorities were informed in writing beforehand about our campaign. At the same time, we also provided them with suggestions about how best to react to the telephone enquiries of residents. Despite these measures, many local councils have felt overwhelmed by the thousands of telephone enquiries they have received from the public.

The central government and in particular, the Ministry of Transport has been exceptionally happy with our campaign, particularly the bottom-up approach.

**Phase 2 (October 1998)**
In this phase, a help desk/information line was established so that people could call in for more information.
This help desk can provide the caller with the following services:
1. General information about the Sustainable Safety start-up programme.
2. Information in the form of a brochure which can be sent to the caller containing instructions about how to achieve the realisation of a 30 km zone in their own neighbourhood.
3. The caller can be connected to a telephonic consulting service from traffic and procedural support specialists.

The number of callers on a yearly basis: approximately 13,000

During 1999 approximately 1000 people made contact with the traffic specialists consulting service for further advice and support. A great number of people visited the internet site and requested the brochure.

The TV-commercial “30 km zones in front of your own home” was broadcast 633 times during 1999. In other words, 52 times per month and 12 times per week.

The broadcasting was free of charge. This means that we generated over 1.2 million Dutch guilders (545,000 EURO) of free-publicity.
Phase 3 (December 1998)
Within the framework of the start-up program, local councils were able to submit their subsidy applications for an expansion of the number of 30 km zones to central government until the end of December 1998. Because these applications came in rather slowly, a "marathon" was organised in the middle of December in order to symbolically and playfully stimulate local councils to get their applications in on time. The final result of this was that 99% of the local councils applied for subsidies to the Ministry of Transport.

Phase 4 (May 1999)
In 1999 the local councils elaborated their plans further. It became apparent that for the realisation of all of the plans, an amount of 400 million Dutch guilders was necessary (= 182 million EURO) while there was only 135 million Dutch guilders (= 61 million EURO) available within the framework of the subsidy arrangement.

As a result, local councils could well receive less subsidy per project than they have accounted for. This in turn could lead to a delay in the realisation of the 30 km zone expansions. We have tackled this problem by requesting the Ministry of Transport to make more funds available. When it appeared that the minister in question was not prepared to do this, we began a political lobby directed at parliament. This has led to some serious and animated discussions between the parliament and the minister but has not yet led to any extra funding.

Phase 5 (May 2000)
In this phase, the support framework for the residents needs to be elaborated further. Specific information per situation in the form of information leaflets can be supplied.

An instruction book "Duurzaam Veilig bij 30 km/uur" ("Sustainable Safety at 30 km/h") has been made. With the use of this, residents are able to think along with local councils and exert their influence on planning. We are also busy renewing and improving the website and further elaborating the "30 is prettig -straatfeesten" ("30 km zones are good for street parties") idea.

Finally, in light of the financial problems I have just outlined for you, we would like to spread information about effective and cheaper measures. It is possible to bring safety into the streets by using inexpensive measures and we have made a beginning on this by drawing up an inventory of cheaper options. The first report has been completed and this information shall also be placed onto the website. The results of this phase are still hidden in the future.
Finally
Sustainable road safety is a concept that we can allow ourselves to have high expectations for in The Netherlands. The expansion of 30 km-zones in particular, leads to more safety and freedom of movement for vulnerable members of the community. This is why we, the Dutch Traffic Safety Association - 3VO, have put a great deal of energy into it.
The start-up programme demands a major effort, especially on the part of the local authorities for roads. This effort can lead to good results if the government and the public are able to put their shoulders to the wheel together. The Dutch Traffic Safety Association - 3VO can contribute expertise, knowledge and influence to this process.
If you look to the different phases of the campaign, you can see there are different clients in each phase. We started with the “Please slow down - Thank you” campaign. At that time it were the car drivers who were our main clients. In the “30 km zone” campaign our customers in phases 1, 2 and 3 were the local citizens and central government and in phase 4 local authorities and parliament. In the current phase 5 our clients are again the local citizens and the different authorities.
A co-operatively felt responsibility combined with a positive effort from all "stake-holders" is the best guarantee for more safety in the future.
ROAD SAFETY ON THREE CONTINENTS
20 – 22 SEPTEMBER 2000, PRETORIA, SOUTH AFRICA.

"An approach to create support for speed reduction",

Drs. Jeroen Kempen, Projectmanager of the Dutch Traffic Safety Association - 3VO.

Substainable Safety

• Start-up programme
• Subsidy arrangements
• Expansion of 30 km zones
Residents participation

- Mobilisation and activation
- Support and acceptance

Public Campaign “30 km zones”

Aims:
1. Expansion of 30 km zones
2. Stimulation of residents
3. Creation of support
Public Campaign “30 km zones”

Phase 1 (May 1998)

• TV-spot, internetsite, posters, etc.

Message: Residents make contact with local authority.

Results: Many people had contact.
Public Campaign “30 km zones”

Phase 2 (October 1998)
- Helpdesk/ information line
- Brochure
- Consulting service
- Message: more information and services for residents.
Results: TV-spot: 650x in 1999
1000 people contacted consulting service in 1999

Public Campaign “30 km zones”

Phase 3 (December 1998)
- Marathon

Message: Playfully stimulate local councils to get their application in on time.
Result: 99% of the local councils applied for subsidy
Public Campaign “30 km zones”

Phase 4 (May 1999)
• More plans than money available
• Delay in realisation of 30 km-zones

Message: Political lobby directed at parliament
Result: Serious discussion between parliament and minister.

Phase 5 (May 2000)
• Instruction book
• Streetparties
• Renewing website

Message: In light of financial problem using effective and inexpensive measures
Result: Future challenge
Public Campaign “30 km zones”

Who are the cliënts?

• Roadusers
• Residents
• Ministry of Transport
• Local authorities
• Parliament

End
Session 14   Traffic Laws, Traffic Control and Enforcement Techniques

Monitoring police enforcement: synthesis of guidelines
*Victoria Gitelman*

Fasten seat belts! – Traffic accident situation in Germany and risk homeostasis theory
*Falk Kalus*

Speed, traffic cameras and justice: lessons learned in two societies
*Rob Reid Smith*
MONITORING POLICE ENFORCEMENT: 
SYNTHESIS OF GUIDELINES

by Victoria Gitelman¹, A. Shalom Hakkert¹ and Christhard Gelau²
¹Transportation Research Institute, Technion, Israel
²Federal Highway Research Institute, Germany

Abstract
The main role of traffic enforcement is seen as deterring road users from committing offences, which can be related to road crashes and injuries. To apply effective enforcement strategies and tactics, the enforcement activity needs to be systematically monitored. As this concerns, to a great extent, the enforcement effects, monitoring enforcement implies monitoring the actual levels of non-compliance and assessing the impact of enforcement operations on traffic behaviours and road safety. At present, the majority of enforcement activities are not assessed in a systematic manner. Normally, especially as to routine enforcement, no data analysis precedes the activity, no quantitative targets are set, no specific methods are selected, and no monitoring is carried out. Moreover, across the EU as a whole, police enforcement activity is not always considered as an integral part of traffic safety policy, due to little coordination between road safety experts and police staff. At the same time, some countries (e.g. Finland, the Netherlands, Sweden) have already developed elements of monitoring mechanisms and a summary of their experience would be of help to other countries.

Concerning specific enforcement projects, different methods are applied around the world to assess the enforcement effects. Although most of the methods are suitable for evaluation purposes, they differ in definitions, assumptions, terms, etc. so that a comparison of outcomes between countries is not easy or sometimes impossible. Non-compliance data are often missing or defined in site-specific terms; enforcement data is also a problem, because it is frequently unclear what the base level of enforcement was in the project assessed and how the enforcement project was actually performed.

Therefore, within the framework of the EU-project ESCAPE it was initiated to develop a background for the synthesis of guidelines for monitoring routine police enforcement based on practical measures of non-compliance in driver behaviour and other available data. As main enforcement areas of interest were selected alcohol-impaired driving, speeding and use of seat belts; also, when available, a relevant summary of methods could be provided for other enforcement areas (e.g. red-light running, sign compliance). The study included: 1) An overview of practices accepted for monitoring police enforcement in several European countries (with the help of a questionnaire distributed among the police commanders and relevant experts); 2) A review of regular surveys for the systematic evaluation of road user behaviour (as available in European and other countries); 3) Drawing out relevant methods and tools for monitoring police enforcement, which were developed in specific enforcement projects, based on a recent literature review. Following the reviews performed, the main components of the monitoring mechanism were specified and methodical rules for the performance of regular surveys of driver behaviours, measuring enforcement activity and evaluating enforcement effects, were proposed. The findings were synthesized in the form of guidelines for monitoring routine police enforcement.
MONITORING POLICE ENFORCEMENT:  
SYNTHESIS OF GUIDELINES

by Victoria Gitelman\(^1\), A. Shalom Hakkert\(^1\) and Christhard Gelaue\(^2\)  
\(^1\)Transportation Research Institute, Technion, Israel  
\(^2\)Federal Highway Research Institute, Germany

1. Background

Traffic police enforcement is one of the preventive activities to reduce road crashes. The main role of traffic enforcement is seen as deterring road users from committing offences, which can be related to road crashes and injuries (ETSC, 1999). The problem is still urgent due to the high numbers of road crash fatalities and injuries in the European Union (EU), whereas traffic offences are believed to be a major contributing factor to a large proportion of road crashes. Considering traffic behaviour, it is broadly admitted that most road users violate the regulations to one or another extent, by sometimes exceeding the speed limits, driving in the wrong lane, not slowing down at an intersection, etc. (OECD, 1999). So, it is not the case of removing a small group of violators in order to solve the problem, as this happens with other crimes and misdemeanors. As, on the one side, there are police forces, which are generally limited by the available resources and by their established priorities, and, on the other side, the public at large is involved, a special deterrence mechanism needs to be applied to influence the situation. The cornerstone of this mechanism is the subjective probability of detection when committing an offence (Rothengatter, 1991).

As with any activity, enforcement activities gain in effectiveness if they are problem-oriented, targeted, have specified objectives and success criteria and are monitored in terms of process and product (ETSC, 1999). At present, the majority of enforcement activities are not assessed in such manner. Normally, especially as to routine enforcement, no data analysis precedes the activity, no quantitative targets are set, no specific methods are selected, and no monitoring is carried out. No wonder that the effect of such enforcement is frequently intangible. Moreover, across the EU as a whole, police enforcement activity is not always considered as an integral part of traffic safety policy, due to little coordination between road safety experts and police staff. At the same time, some countries (e.g. Finland, the Netherlands, Sweden) have already developed elements of monitoring mechanisms and a summary of their experience would be of help for other countries.

The need for effective monitoring also stems from the fact that police resources are always limited. The relative ability of the traffic police to influence road traffic also diminishes over time, due to the permanent increase in the number of drivers and vehicles registered and the vehicle-kilometers traveled versus tiny changes in the number of police staff (e.g. Freedman and Paek, 1992; PACTS, 1999). In addition, there are many other pressing problems that the police forces face.

Concerning the availability of enforcement data, several studies (e.g. Bjornskau and Elvik, 1992) reviewed a number of experiments where enforcement was increased considerably. The majority of projects produced reductions in the violation rates and

1
most could also show a decrease in accident frequencies. However, it is frequently unclear what the base levels of enforcement were and how the enforcement project was actually performed. Not rarely "heavy" or "active" police presence is mentioned in a study not being explained numerically. In many countries, a system of indicators for enforcement activity is not developed. Neither Police Headquarters nor road safety authorities are regularly using such indicators. As a result, first, the findings of various studies cannot be compared in a meaningful way; second, the actual reasons for the enforcement success or failure are less well understood; and finally, relevant managerial information, which could form the basis upon which enforcement can be optimized, is generally unavailable.

2. Study's Objective and Method

To apply effective enforcement strategies and tactics, the enforcement activity needs to be systematically monitored. As this concerns, to a great extent, the enforcement effects, monitoring enforcement implies monitoring the actual levels of non-compliance and assessing the impact of enforcement operations on traffic behaviours and road safety.

Therefore, the aim of this study (which was conducted within the framework of the EU project ESCAPE) was to provide the background for the development of guidelines for monitoring routine police enforcement based on practical measures of non-compliance in driver behaviour and other available data, and to sum up the findings in the form of a reasonable set of instructions for application. The main enforcement areas of interest were the areas of alcohol-impaired driving, speeding, use of seat belts, in which there is extensive experience of assessment work, and also, when available, a relevant summary of methods was provided for other enforcement areas (e.g. red-light running, sign compliance).

Generally, the guidelines were derived from a review of literature and the available experience in European countries. The study (Gitelman & Hakkert, 2000) included:

(1) An overview of practices accepted for evaluating police enforcement in different European countries (with the help of a questionnaire distributed among police commanders and relevant experts);

(2) A review of regular surveys for the systematic evaluation of road user behaviour, which are available in European and other countries;

(3) Drawing out relevant methods and tools for monitoring police enforcement, which were developed in specific enforcement projects, based on a recent literature review;

(4) Summarizing up-to-date monitoring techniques for the main enforcement areas.

3. Overview of current practice

When traffic police enforcement is considered as part of the safety-promoting activity in the country, there are elements of planning the enforcement activity and of evaluating the effects. As in any working body, main activity figures and the outcomes are considered within the Police and are reported to the overseeing agencies (or directly, to the Government). Differences among the European countries exist as to the
level of development of this monitoring mechanism, i.e. the data and analyses applied at different monitoring steps, adopted interpretation of the enforcement targets, kinds of disaggregation of the components, etc. The monitoring structure and components are generally dictated, first, by the administrative structure and responsibilities of the police forces in the country, and second, by the history of traffic enforcement activity in the country as systematically working (or not) in cooperation with research bodies. The latter usually depends on how long road safety has been treated as a nationally important problem in the country.

Practices for monitoring police enforcement in European countries, were analyzed for five countries with more than 30-year experience of systematic activity in the road safety field: Finland, France, Germany, the Netherlands and Sweden (the questionnaires were answered by representatives of the Police Commands and experienced researchers in the field). The main interest was in the identification of the basic stages/ components of the monitoring process, bodies involved, background data used and accepted reporting routines in a specific country. Four main stages of the monitoring process were discussed:

- Defining enforcement targets.
- Systematic reporting on enforcement activity.
- Evaluating enforcement effects.
- Distributing the evaluation results.

For example, Table 1 illustrates the process of monitoring police enforcement in Finland.

It was found that the monitoring practices in the countries reviewed have many common features whereas in Finland and Sweden the monitoring mechanism is more explicit than in other countries.

Concerning the planning and targets' definition stage, the following regularities were noted:
- The enforcement targets always ensue from the national safety targets, defined by the National safety program;
- The annual police plans are coordinated with the governmental bodies, responsible for the national safety programs. These plans are developed on national or regional levels;
- The targets are always given in accident/casualty terms but sometimes also in terms of behaviour changes in the main enforcement areas, i.e. speeding, alcohol-impaired driving, seatbelt use. The latter explicitly characterizes the Finnish practice and is, to some extent, in use in Sweden and the Netherlands. The plans can also include figures on enforcement intensity (working hours) and violations;
- The disaggregation of the annual plans can follow up to the local police units.

In reporting enforcement activities the following features were seen:
- In most countries (except for Germany) the reporting rules are defined within the police forces. The most regular reporting takes place in Finland and Sweden, where multi-level information systems have been developed for this purpose;
Table 1. Characteristics of practice for monitoring enforcement in Finland

<table>
<thead>
<tr>
<th>Stage 1. Defining enforcement targets</th>
<th>Disaggregation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting point</td>
<td></td>
</tr>
<tr>
<td>Traffic safety targets, set by the National Traffic Safety Plan</td>
<td>Provincial Police Commands determine the action plans of the local police districts; Chief of the NTP – the action plans of the Provincial NTP divisions; Chief of the division confirms the action plans of the local units</td>
</tr>
<tr>
<td>The Supreme Police Command sets annual targets for traffic enforcement and confirms annual action plans of the police command of each province and the National Traffic Police (NTP)</td>
<td></td>
</tr>
<tr>
<td>Annual police plan</td>
<td></td>
</tr>
<tr>
<td>Targets in terms of</td>
<td></td>
</tr>
<tr>
<td>Road traffic casualties (numbers of fatalities, injuries) and behaviour indicators (share of driving at excessive speeds; drunk drivers per 10,000 drivers; share of persons neglecting seat belt use in front seats of cars outside urban area)</td>
<td></td>
</tr>
<tr>
<td>Disaggregation</td>
<td></td>
</tr>
</tbody>
</table>

| Stage 2. Systematic reporting on enforcement activity                                              |                                                                                                                                                  |
| Tools and responsibilities                                                                       |                                                                                                                                                  |
| An on-line information system is in use (over 10 years) where each policeman is responsible to feed the current data into the computer. |                                                                                                                                                  |
| Data collected                                                                                   |                                                                                                                                                  |
| Working hours, number of tickets, written warnings, etc.                                        |                                                                                                                                                  |
| Annual report                                                                                    |                                                                                                                                                  |
| Annual reports of the police and of the different units include the important summary figures and the comparisons with previous years. The NTP headquarters make comparisons between the four regional divisions. |                                                                                                                                                  |
| Other reports                                                                                    |                                                                                                                                                  |
| Cumulative monthly figures can be produced; each unit can take desired reports from the system. It is possible to follow inputs and outputs of a certain police activity. |                                                                                                                                                  |

| Stage 3. Evaluating enforcement effects                                                           |                                                                                                                                                  |
| Information sources applied                                                                      |                                                                                                                                                  |
| Accident statistics; Findings of accident investigation teams; Results of systematic monitoring of traffic attitudes; Results of systematic monitoring of traffic behaviours - usually more than one source is applied to correctly evaluate the effects. |                                                                                                                                                  |
| In 1999 – the NTP implemented a survey of fined drivers on the quality of the traffic enforcement work; more than half of the drivers told that they were positively influenced by the police. |                                                                                                                                                  |
| Internal evaluation                                                                              |                                                                                                                                                  |
| Inputs and outputs of the police units are summarized on the regional level and reported to the chief of the NTP |                                                                                                                                                  |
| Overall evaluation                                                                               |                                                                                                                                                  |
| The National Traffic Safety Council annually evaluates the activities and results attained in the field of traffic safety, but no direct effect of enforcement is assessed. Many research studies have handled the effects of traffic enforcement. |                                                                                                                                                  |

| Stage 4. Distributing the evaluation results                                                       |                                                                                                                                                  |
| Internal                                                                                          |                                                                                                                                                  |
| Action plans with the evaluation of an earlier year are available in electronic form for each police unit. |                                                                                                                                                  |
| External                                                                                         |                                                                                                                                                  |
| Annual reports of the police are delivered to all interested bodies. The police have Internet-pages. Police units offer plenty of current information on traffic safety activities and traffic safety situation to mass media. Summaries of accident, behaviour and attitude data as well as the results of their over-time comparisons are systematically published by the relevant governmental bodies. |                                                                                                                                                  |
The enforcement data collected are usually working hours and sanctions produced (tickets, warnings, etc.) but sometimes the numbers of speed and alcohol controls are also reported;

The periodic activity reports are usually produced by the police, except for France where this is done by the governmental statistical body. On the national/regional level these are annual/semi-annual reports; for the local level also quarterly or even monthly figures are provided.

The reports are generally applied for internal police purposes whereas in Sweden strict control of the figures is performed by the National Road Administration.

As to evaluating the enforcement effects, this remains a problematic issue in all countries. Based on all available information sources, i.e. accident statistics, results of behaviour observations, driver attitudes and offence data, the governmental statistical bodies evaluate the overall trends in the road safety situation in the country but these trends, generally, have no direct links to the enforcement efforts applied. To ascertain the enforcement effects, usually, special evaluations are performed by research institutes, as commissioned by the overseeing agencies. While evaluating the effects of routine enforcement seems to be problematic, evaluating the effects of specific enforcement projects is considered as a routine, at least, in the Netherlands where a manual for planning and monitoring enforcement projects was developed in 1995.

Concerning the distribution of evaluation results, the governmental or statistical bodies annually publish the summaries of accident, behaviour and offence figures in the country, and these are usually presented to the public, through the mass media. Sometimes, semi-annual figures are available on a regional/local level. Very close cooperation with publicity, on all levels, is characteristic for the Finnish police, which enables public access to both summary and current enforcement figures. As to relevant feedback for the police forces, the police usually have direct access to the accident/behaviour figures, even prior to their official distribution. Besides, special summary reports on enforcement activity return to the police units in Finland and France, whereas in Finland these reports can also be produced for any police subdivision and any time period.

4. Monitoring driver behaviour: regular surveys

One of the basic sources for monitoring routine enforcement is a system for monitoring traffic behaviours, which comprises a series of annual surveys, with regards to one or several categories of traffic behaviour. Such surveys take place in Finland, the Netherlands, France, UK, Sweden, USA and other countries. Annual repetitions of the same measurements enable to observe traffic behaviour trends within the surveyed area and the impact of countermeasures applied. The experience shows that a system for monitoring traffic behaviours functions on a regular basis when it is initiated and supervised by a governmental body (Ministry of Transport, Road Safety Authority) and the data are collected and processed under the supervision of a National Road/Safety Research Institute or a Governmental Statistical body. There are proofs from several EU countries (e.g. Finland, the Netherlands, the United Kingdom) that a series of behaviour indicators, accompanied by relevant research studies, serve as a background for the evaluation and development of enforcement
measures, especially in the drinking-and-driving field. For example, since the mid seventies, when breath-test equipment became widely available to the police and for random surveys, alcohol-impaired driving has become one of the principal enforcement areas in Finland. During recent years, some 30 per cent of traffic enforcement by the local police and 15 percent of the National Traffic Police is targeted at drink-driving. The problem always gained extensive mass media coverage as the Central Organization for Traffic Safety chose to attain changes in the traffic attitudes of the public. Since the early nineties, the police initiated systematic enforcement campaigns with results reviewed in public. Not surprisingly, today, nine out of ten Finnish drivers support the present level of traffic enforcement (Makinen, 1999). Some 40 percent of drivers are tested annually. The number of those caught for drunken driving has fallen during the past ten years from 33 out of 1000 to 14 out of 1000.

The methodical rules, learnt from the regular surveys observed, were summed up as follows:

(1) a system of automatic measuring points distributed across the road network is desirable for regular speed measurements. When such a system is not available, radar-measurements performed from a non-suspicious car, parked on a roadside, are also possible. Observations take place on 20-40 sites, providing a representative sample of different road categories. The duration can change from site to site (according to sample demands, traffic volumes, etc.) or, in the case of automatic measurements, hourly speed distributions for 1-2 working days are considered for each site. Special techniques for averaging results are developed, to provide weighted values for each road and lane type (or speed zone). If possible, the figures are presented separately for day- and night-time and for different seasons. Estimated figures are mean speeds and percentages of vehicles traveling over the speed limits. The presentation of speed distributions by 10 kph intervals for different road categories is proposed as more informative for enforcement purposes.

(2) Alcohol checks are performed in cooperation with police teams, which stop the vehicle and ask the driver to take a breath test. Two ways for building a sample are mentioned: one is stopping every vehicle, which is passing a control point (whereas control points are selected such that the passing traffic is representative), and the other is when the vehicles tested are randomly chosen from the traffic (a special procedure is needed). The final sample should include, at least, several ten thousands of measurements. The observations take place in the hours of expected higher level of alcohol-impaired driving, i.e. on weekend nights. Estimated figures are percentages of drivers impaired under the legal level, over the legal level and much more than the legal level. If possible, the figures are also provided for different administrative districts.

(3) Safety belt surveys are carried out during the warm but working season (e.g., May; August-September; October) and last, on average, two weeks. A wide range of sites is embraced to provide representative figures for urban and rural areas, long-distance and local traffic, high and low traffic volumes, weekday and weekend hours. Two types of sites are mentioned: intersections, where the observation is performed during the red phase of the traffic lights (or when the vehicle stops/slow down before traffic signs), and at entrances to the car parks and shopping centers. Usually, the unobtrusive method is applied whereby the observer
only registers the details that can be seen through the window. However, the “obtrusive” method is also possible when the observer asks the driver’s/ passenger’s age or when the vehicle is stopped by the police in connection with, for example, the drink-driving surveillance work. The number of observation hours per site varies in accordance with sample demands, traffic volume, etc. The total sample of vehicles checked should be of several ten thousands, at least. A special procedure is developed for weighting values from different sites. Wearing rates are estimated for driver, front- and back-seat passengers, sometimes for child restraints. If possible, separate figures are presented for urban/ rural areas, different traffic and vehicle types. When the data subdivision is performed, the specific sample size estimated is desired to be of several thousand observations (smaller samples are also applied, e.g. when child restraints are considered, but with reservations).

Between the years comparisons of indicators are mainly visual, to indicate overall increasing or decreasing trends of changes. In-depth analysis of long-term trends, involving explaining factors, is performed by research studies. Relevant examples are the studies which examined a decline in drinking and driving which was observed in many European countries over the eighties, following intensive enforcement and legislation changes. For example, Noordzij (1994) discusses this decline in the Netherlands, as seen in the results of roadside surveys and in accident statistics; Clayton and Everest (1994) discussed trends in the UK alcohol related road accidents, and found that the proportion of all car driver fatalities having BACs in the bands between 80 and 200 mg/100ml fell from 25 to 10 percent over the decade and that these trends were consistent with the results of roadside surveys and with the interview statements of male drivers.

5. Measuring enforcement activity

As mentioned before, measuring the efforts invested by the police into traffic enforcement remains a problem in many countries. Published reports of police activity (where they exist) usually relate to the total offence figures, the available police staff and enforcement equipment, and sometimes, the numbers of speed and alcohol controls. As generally agreed, these figures provide merely superficial characteristics of the activity performed and reflect neither strong nor weak features of the force deployment and the enforcement tactics applied.

Referring to published enforcement studies, several ways for measurement of enforcement activity can be found: (a) a general overview of available police resources in a country; (b) consideration of citations; (c) specific measures of enforcement intensity. A general overview of police resources was performed, e.g. by Freedman and Paek (1992); Zaidel and Makinen (1997), where the enforcement level was determined by comparing the police staff number with some objective measures of need for police traffic enforcement services: the number of vehicle miles traveled, the number of licensed drivers or the general length of public roads. Following the same principle, Raub (1988) developed a model for projecting the required number of police officers in the future. Raub’s model estimates the future workload (annual number of hours spent on traffic police services), based on the number of vehicle
miles traveled – for primary highways, and based on the total rural population and average daily traffic – for rural highways.

Another approach is when the routine work of traffic police is analyzed by screening the characteristics of citations given and contrasting them to corresponding road types, driver behaviour and accident data breakdowns. This was applied by French researchers (e.g. Alouda and Jayet, 1995), as to speed and alcohol enforcement in built-up areas. When similar time and space parameters were applied for breaking down the available data on speed measurements/alcohol checks, the accident statistics and the offences registered, a general discrepancy was identified between the behaviour and accident characteristics versus the offenses considered. The time and space characteristics of the traffic police strategies appeared to be mostly dependent on the structure of working hours of each agency.

As to specific measures of enforcement activity, in the speeding area, these are, for example, vehicle-hours of patrol per day, number of kilometers enforced per vehicle-hour per day, monthly numbers of site visits, the number of offenses detected per site visit (Leggett, 1988). Vaa (1997) analyzed the enforcement activity levels in terms of enforcement hours during the project period, distributed according to method (stationary enforcement, mobile or parked car) and week. The enforcement hours during the project were also estimated, e.g. by Bloch (1998), the number of officers per patrol unit – by Jones and Lacey (1997). A different interpretation of enforcement intensity was applied by Waard & Rootjers (1994) who manipulated the level of apprehension for detected speeding drivers.

In the studies of alcohol-impaired driving, along with the offence numbers, several intermediate indicators are also applied, such as the total number of drivers stopped, the number of negative and positive breath-tests, the total number of hours spent by police officers on random breath testing (RBT) (e.g. Mercer et al, 1996). To provide a more general indicator of activity, the number of tests are contrasted to the number of license holders, or a rate of area population checked, per month, is estimated.

In two Israeli studies of general enforcement (Zaidel et al, 1994 and Hakkert et al, 2000), a wide range of indicators was proposed aspiring to provide a comprehensive picture of activity of the National Traffic Police. Three groups of police activity indices were considered: inputs - the application of police forces and instruments for field enforcement activity; outputs - the level of actual police presence in the field and the citations given; and efficiency indices – the performance versus plan and resource utilization ratios. The enforcement periods were compared in terms of these indices.

As became obvious, no sound basis is yet available to strictly determine demands as to the indicators of routine police activity. Nevertheless, based on the experience considered, some indices were recommended as both measurable and indicative:

in the drinking and driving enforcement area - the total number of drivers stopped, the number of negative and positive breath-tests performed, the offence numbers and the total number of hours spent by the police officers on RBT (the comparative ratios of these numbers are easily applicable and very informative, e.g. the number of drivers stopped per RBT hour);
regarding the performance of automatic cameras - the number of vehicles processed, the number of locations monitored, the number of cameras in operation, the hours worked and the tickets issued;
as to enforcement of seatbelt use - the citation numbers, their splits by the car occupants involved and, when possible, the total number of drivers controlled by the police;
as to conventional speed enforcement and other fields, the relevant set of indices is vehicle-hours of patrol with the number of kilometers enforced, the numbers of site visits and the number of offenses detected per site visit.

Depending on the purposes of consideration, these can be weekly, monthly or yearly figures, applied to the whole road network or to specific enforcement sites/area.

6. Evaluating enforcement effects

According to the concept of enforcement mechanism (e.g. OECD, 1999), in general, three types of information can be analyzed to evaluate the enforcement effects, i.e. data on changes in drivers’ behaviour, drivers’ attitudes and accidents. The relevant choice is mainly dictated by the enforcement terms, i.e. by the scale and duration of the activity assessed (Table 2). Behaviour data are considered as the most suitable in most cases.

Table 2. Choice of type of information for evaluating enforcement effects, depending on enforcement terms

<table>
<thead>
<tr>
<th>Duration of enforcement activity</th>
<th>Scale of enforcement activity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>National/ regional</td>
</tr>
<tr>
<td>Short-term (up to several months)</td>
<td>Behavioral observations,</td>
</tr>
<tr>
<td></td>
<td>Drivers’ surveys (optional)</td>
</tr>
<tr>
<td>Middle-term (several months- one year)</td>
<td>Behavioral observations,</td>
</tr>
<tr>
<td></td>
<td>Drivers’ surveys,</td>
</tr>
<tr>
<td></td>
<td>Accident analysis</td>
</tr>
<tr>
<td>Long-term (one year or more)</td>
<td>Behavioral observations (A),</td>
</tr>
<tr>
<td></td>
<td>Drivers’ surveys (A),</td>
</tr>
<tr>
<td></td>
<td>Accident analysis (*)</td>
</tr>
</tbody>
</table>

Where: “A” indicates the applicability of the results of regular behaviour and driver opinion surveys; “∗∗” – an extensive analysis of accident trends, accounting for many contributing factors (legislative changes, economic growth, etc.), can be carried out.

Special behaviour surveys
When the effects of short-term and local enforcement activities, rather than annual and national-scale, are considered, special surveys of driver behaviour are applied. These are performed by external research bodies, as commissioned by the police or overseeing agencies. A brief summary of methodical rules for the survey performance, in several behaviour fields, which were drawn from more than 40 enforcement studies reviewed (Gitelman & Hakkert, 2000) is given in Table 3.

Drivers’ opinion surveys
In addition to direct observations of driver behaviour, driver opinion surveys can provide an indication to the police and other relevant agencies, concerning the effects of enforcement and other safety activities. Depending on the survey frequency, scope and purposes, three groups of such surveys can be defined:
Table 3. Summary of rules for special (short- and middle-term) surveys of selected behaviours

<table>
<thead>
<tr>
<th>Behaviour type</th>
<th>Equipment applied</th>
<th>Duration of measurements</th>
<th>Number of sites</th>
<th>Control group</th>
<th>Estimates and comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>(1) permanent inductive loops or (2) hand-held speed guns</td>
<td>with (1) – several weeks/months, with (2)– one-two days; Performed at least twice, before- and during the enforcement operation</td>
<td>Depending on enforcement area, 5-20 locations</td>
<td>Recommended; should be comparable with the enforcement sites in traffic and road characteristics and in weather conditions</td>
<td>Estimates: mean speeds and the percentage of vehicles exceeding the limits (or the limit plus tolerance; or the limit plus 10-20 kph); 85th percentile speeds and speed variance. Estimates are presented for different road and lane types or speed zones. After-before comparisons of the speed indices are performed, accounting for changes observed on control sites. (Significance of changes is examined, by relatively simple statistical tests, e.g. t-test).</td>
</tr>
<tr>
<td>Seatbelt use</td>
<td>Simple “unobtrusive” observations: the observer writes down the relevant details after he has looked into the vehicle, at a constant pace.</td>
<td>2-4 hours or several hundred observations per site, to provide a total sample of several tens thousands, per round; 3 rounds of observations are performed: baseline, towards the end of the enforcement campaign and after the campaign completion</td>
<td>10-20 locations of typical traffic flows, incl. intersections, mall entrances or gates</td>
<td>Recommended, with similar number of sites, but within another community - definitely not influenced by the campaign</td>
<td>The list of details recorded per vehicle depends on the survey purposes: this can be merely driver’s belt use or in combination with driver’s age, sex, vehicle type, belt use by the front passenger, direction and line of travel, hour, etc. Estimates: from simple driver’s use rate to the variations of the indicator in context of other characteristics. Evaluating the enforcement effect, after/before comparisons with a control group are applied.</td>
</tr>
<tr>
<td>Red-light running</td>
<td>Camera, automatic or hand-held</td>
<td>Several days, for different time periods, to provide a sample of several ten thousands; Time of day and total number of hours observed should match for before and after rounds</td>
<td>10 or more intersections</td>
<td>Recommended</td>
<td>Estimates: violation rates per 10,000 vehicles or per red-light cycle; if possible, separately for straight and turning vehicle movements, different vehicle types and traffic volumes After/before comparisons of violation rates, as opposed to a control group; for approaches influenced versus not influenced by the enforcement</td>
</tr>
</tbody>
</table>

For drink-driving - the rules of regular survey are applied; for after/before comparisons, two rounds of observations and a control region are recommended.
a) systematic surveys, i.e. nation-wide, usually performed on an annual/biennial basis and comprising a wide range of safety issues;
b) specific surveys, i.e. focused on a specific enforcement area, sometimes nation-wide but not representing part of a regular survey;
c) surveys as components of enforcement studies.

A systematic survey is usually initiated by the national road safety authority with the purpose of monitoring key community attitudes towards road safety issues. As these surveys frequently comprise such issues as self-reported driving habits as to compliance with the traffic laws; perceived level of compliance by other drivers in the same enforcement areas; the perception of current enforcement activity, their findings can be accounted for while determining current enforcement strategies and tactics. Conversely, the survey can provide indications of a high level of drivers’ awareness of the police enforcement efforts in the main enforcement areas. For example, the national Australian survey on road safety issues is conducted since 1986 (Mitchell-Taverner et al, 1995). Recent years’ findings demonstrated that speed and alcohol were steadily recognized by the community as the primary issues in road safety. There are indications of a high level of awareness of police enforcement efforts in both areas: in 1995, three out of five people reported that the amount of speed enforcement had increased over the past two years; nearly two thirds of reporters saw the RBT operations in the past six months and 19% said that they had been tested.

Specific surveys are conducted to evaluate the influence of some changes, which took place in a specific enforcement area (but do not present a component of a monitoring program of an enforcement project). To ascertain the changes (or the lack of changes) in drivers’ attitudes, usually, the results of two similar surveys are compared or, alternatively, the responses of different population categories are contrasted. For example, Aberg (1993) investigated the effect of the introduction of a change of the legal BAC limit from 0.05% to 0.02% on Swedish drivers’ self-reported drink-driving. The questions concerned driver’s attitudes, social norms, expectations and evaluations with regard drunken driving, knowledge of the law, and personal drinking habits. Almost no changes were identified after the implementation of the new law. Corbett and Simon (1999) examined the effects of various strategies related to the deployment of speed cameras (in UK), based on drivers’ responses. The main finding was that, according to self-reported measures, camera deployment markedly reduces drivers’ speeds.

Drivers’ surveys are frequently applied as additional monitoring tools of the enforcement operations in different enforcement areas (e.g. Jones and Lacey, 1997; Retting et al, 1998). Such a survey usually estimates drivers’ awareness about the enforcement operation, perceived changes in police activity, perceived changes in the risk of apprehension for a violation, and self-reported changes in driver behaviour.

In all cases, strict methodological rules need to be defined for the survey performance. This concerns the sampling method, which is supposed to provide a representative picture of the relevant driving population, sample size and the procedures applied, which should guarantee the desired quality of estimates. A sampling procedure based
on characteristics of drivers' behaviour, can provide more detailed indications of existing weaknesses in enforcement practice (Waards & Rooijers, 1994).

**Accident analysis**

Due to the complex nature of road accidents, accident changes attributable to enforcement activity are usually not apparent. A reasonable statistical relation can be established when both enforcement activity and road accidents are considered over a long time period. Two principles are essential to properly evaluate the enforcement effect: first, a correct definition of the target accident group and, second, developing a model which accounts for confounding factors.

Based on the experience of enforcement studies (e.g. Leggett, 1988; Elvik, 1997; Mercer et al, 1996), as target accident groups can be recommended:

- In the *speed enforcement* area - all injury accidents (or casualty numbers), also subdivided into several severity categories, i.e. fatal, serious, slight, damage only accidents (or fatal, serious, slight injuries);
- In the *drinking and driving enforcement* area – the numbers of driver fatalities/serious injuries with high blood alcohol concentration and their percentages in the total number of driver fatalities/serious injuries of the same crashes; or, when the accident registration data do not allow for the previous selection, the number of serious crashes (injuries) that occurred in high-alcohol-hours. The latter are the hours of week, when as defined in the country, illegal drink-driving is more likely to occur;
- In the *seat belt enforcement* area – the number of serious injuries of occupants covered by the seat belt law (or enforcement activity) as opposed to occupants not-covered by the law (the enforcement), and to non-occupants. Alternatively, the use of safety restraints by persons injured in the road accidents, can be examined when this component of accident statistics is reliable enough.

As to the *accident evaluation model*, different forms of odds ratio and time-series techniques are applicable in all enforcement areas. A time-series model is more complex, needs the implementation of professional statistical packages and, thus, should be developed by a research body. The odds ratio approach enables comparatively simple overall evaluations but demands valid control groups. The odds ratio analysis can be performed by a statistical department inside the police. When a strict accident analysis is not performed, visual consideration of overall accident trends, in combination with corresponding changes in behaviour data and, when available, in driver attitudes, provide some background for defining the enforcement effects (but, generally, as not separated from the accompanied publicity and legislative changes). Results of such consideration should be treated as indicative and not conclusive to the same extent as the results of rigorous statistical analysis.

7. **Conclusions**

Based on the best practice and the enforcement studies considered, the following *management principles* can be recommended for monitoring traffic police enforcement:

- The need for monitoring traffic police enforcement should be realized by the Police Commands and the overseeing agencies (National Road Administration, National Road Safety Authority, Ministry of Transport). Both
parties should cooperate in planning the enforcement activity, collecting the relevant data, evaluating the effects and distributing the results.

- Long-term enforcement targets should ensue from the national safety targets, defined by the National safety program. Annual targets should be specified, based on the analysis of recent accident and behaviour data. The analysis should relate to three key issues: problematic locations (where most casualties occur) at problematic times; problematic road users (e.g. rogue haulage companies); and problematic behaviours (e.g. speeding). Selection of high priority enforcement sites should be based on a standardized procedure, which has to be accepted by the police and the overseeing agency and which resulted from preceding research work.

- The annual police plan and annual targets are coordinated with the governmental body, responsible for the National safety program. If, being dictated by the administrative structure of the police, the plan is originally developed on a regional level, corresponding coordination should take place with the regional government. Disaggregation of the annual plan should continue up to the local police units.

- The targets accepted by the police are supposed to be ambitious but attainable and definitely given in quantitative figures. Even realizing the problematic character of this point, the long-term targets should be given in accident/casualty terms. To be more applicable, the enforcement targets should also be given in terms of behaviour changes in the main enforcement areas, e.g. speeding, alcohol-impaired driving, seat-belt use. Figures on enforcement intensity (e.g. working hours, number of controls) can also be included into the plans.

As to circulating the monitoring information,

- Within the police, regular reporting of performed enforcement activities should take place. As the best solution, a multi-level information system should be established for this purpose. Such a system enables both quick data input, as being performed by each police officer after a shift is completed, and producing periodic data summaries for internal and other evaluating purposes. The periodic activity reports can be produced by the police, or by a governmental statistical body.

- Concerning the distribution of evaluation results, the governmental or statistical bodies annually publish the summaries of accident, behaviour and offence figures in the country, and these are usually presented to the public, through the mass media. These summaries should be accompanied by other enforcement figures and by the estimates of enforcement effects (performed by research bodies). Semi-annual and quarterly figures (with regard enforcement activity, driver behaviour and opinion surveys when available) are essential for presentation on a regional/local level.

- As to relevant feedback for the police forces, the police should have direct access to the accident/behaviour figures, even prior to their official distribution. These data can be applied by the police for internal (intermediate) estimates. Besides, special summary reports on enforcement activity and effects should return to the police regions and local units, to provide a basis for a new cycle of enforcement activity.
Fasten Seat Belts! – Traffic Accident Situation in
Germany and Risk Homeostasis Theory*

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Abstract

Risk homeostasis theory (RHT) is a behavioural theory of risk taking in
road traffic. So far, most of the published papers concerning RHT and long
time series are based on econometric methods which are not very well suited
for this purpose. We propose here to address the issue using instead of the
econometric concept of stationarity. We then test the RHT with German traf-
cic accident data and specifically analyze compulsory traffic safety measures
(the penalty for not using seat belts) which are ineffective according to RHT.
Our results, found by using several risk measures, show only weak evidence
for RHT. We find that, due to these safety regulations, accident risk was dis-
placed from more to less severe accidents, as the number of severe accidents
with fatalities and injuries decreased, as did the average severity of accidents
with (bodily) personal damages. Contrary to RHT, we can show that com-
plusory safety measures combined with penalties had a strict positive effect
on the road traffic accident risk.

Key words: Road accidents, fatalities, injuries, severity, risk homeostasis,
time series, stationarity

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les Transports), University of Montréal.
1 Introduction

Risk homeostasis theory (RHT) is a behavioral theory of risk taking in road traffic.\footnote{Wilde [1982, 1984, 1988, 1989, 1994].} The theory is based on the assumption of a constant target risk accepted by road users. Individual driving behavior is chosen so that perceived risk is equal to target risk.

So far all of the published papers supporting or disproving the risk homeostasis thesis refer to field or lab experiments.\footnote{Robertson (1976), O'Neil (1977), Conybeare (1980), Watson et al. (1980), Veling (1984), Shannon (1986).} Following Wilde's risk homeostasis theory is an instrument explaining almost all human behavior in road traffic. Two basic shortcomings concerning RHT can be derived from Wilde's papers and the additional literature.\footnote{McKenna (1985) and Shannon (1986).} First there is a theoretical problem. The theory is valid for a single individual as well as for a group of individuals.\footnote{A group of individuals can be the society (constant target risk level of the society) as well as e.g. the group of car drivers only.} Both meanings are not compatible as McKenna (1985) points out.\footnote{McKenna (1985) shows that RHT does not hold if groups of individuals are considered. Also the results of Conybeare (1980) do not support RHT. The positive risk effects for the group of car users over-compensate the negative effects for the group of non-users (bicyclists, pedestrians). Shannon (1986) analyses British data and find weak support only for RHT in the meaning of Wilde. The rise in the number of killed people in traffic accidents from 1949 until the middle of the sixties and the following drop until 1983 to the 1949 level can not be explained by homeostatic behavior. Adaptation over such a long period is not very realistic for individual behavior described by RHT.} Second Wilde's analysis concerning RHT and long time series are based on econometric methods which are not suited very well for that topic. Particularly a more or less visual analysis of the graphs is not a proper method to conclude long term stable equilibria. A consequent analysis of long time series as performed in this paper was not carried through as yet. The stationarity concept in econometrics is an applicable tool for such an analysis. That concept explains long term equilibria as described in RHT.

The following analysis has to solve two problems. First, we analyze risk measures\footnote{Wilde (1994) considers the risk measure killed people in traffic accidents per population only. In addition we analyse the risk measures severe as well as light injured people per traffic accident.} for stable trend or drift components. These components affect the validity of RHT substantially. Contrary to trend or drift components RHT postulates a stable risk level in the long-run. Second we have to test whether we have stationary risk measures or not. Stationarity means that the risk measures follow an equilibrium path. In the other case we may have stationarity with one or more structural breaks.

In so far the analysis extends the paper of Blum and Gaudry (1999). They analyze determinants of traffic accidents and accident severity. Their paper considers the three level model SNUS\footnote{SNUS = Straßenverkehrsnachfrage, Unfälle und deren Schwere; Road Demand, Accidents and their Severity.} based on a traffic demand function in the first level.
Accident risk is analyzed in two levels: accident frequency and accident severity.\(^8\)

Furthermore we test the validity of RHT with respect to the traffic accident situation in Germany. In particular we analyze the impact of compulsory safety measures (penalty for not using seat belts). The analysis is based on Wilde’s definitions of risk measures with the population as a reference point. That means that we cannot explain the impact of road demand on driving behavior. But in addition we analyze risk measures describing the average accident severity. These measures are independent from population and road demand. They can explain very well the impact of the safety measure considered in the paper.

The analysis goes as follows. In the next section we give a short summary of RHT. In section three we describe the used econometric methods. Section four specifies and analyzes the risk measures. The paper ends with an interpretation of the results with respect to RHT.

2 Risk Homeostasis Theory

The individual *target risk* accepted by a road user is the reference point in RHT.\(^9\) Accepted target risk depends on its costs and benefits. Individual behavior maximizes the difference between costs and benefits.\(^10\) The contrary of target risk is the individual *perceived risk*. It depends on the present (environmental) situation perceived by the road user.\(^11\) Hence perceived risk is the result of the evaluation of the present environmental situation.

Road users compare their target risk with the perceived risk (cf. figure 1). The comparison leads to a decision about the adaptation of their individual (driving) behavior. This adaptation depends on the amount of discrepancies between target and perceived risk. The behavior can be adapted in short terms or in long terms depending on the reason of the discrepancies.\(^12\) Compulsory safety measures drop the perceived risk. That leads to positive reactions in the risk measures considered. Following RHT this positive reaction will be set off by adaptation of individual behavior. That means in the long run that the accident risk is the same as before the safety measure. A rapid behavior adaptation after such a safety measure (e.g. installation of an airbag) is not expected because the change in driving risk will not be realized immediately (lagged feedback).

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\(^8\)A similar procedure is used by Chirinko and Harper (1993). Blum and Gaudry (1999) as well as Chirinko and Harper (1993) consider two risk levels: the risk to suffer an accident and the risk to be injured or to be killed in case of an accident. The last risk level is based on the number of all accidents or the number of accidents with bodily damages. Chirinko and Harper (1993) analyze the Offsetting Behavior Hypothesis (OBH) a concept similar to RHT. They show that people adapt their behavior after installation of new safety measures.

\(^9\)RHT is based on the theory of risk compensation by Wilde (1978). Wilde (1994) gives a complete description of RHT.

\(^10\)Costs can be the accident risk or the accident severity. Benefits can be e.g. saved time costs.

\(^11\)Typical environmental parameters influencing perceived risk are heavy traffic and road or weather conditions. In addition the environmental situation is affected by safety measures (e.g. airbag, ABS).

\(^12\)Very rapid adaptation takes place after a sudden change in weather conditions (e.g. icy road).
Following RHT we have a change only in the perceived risk after implementation of a new safety measure. Hence target risk is the unique external control variable. It is independent of the feedback process. Only a change in target risk can lead to a change in driving behavior and accident risks. In the long-run safety measures are irrelevant to a change in accident risks.

3 Stationarity and Econometric Methods

To analyze the traffic accident situation in Germany we use the econometric concept of stationarity. In this section we give a short introduction to this method. The concept of stationarity is used to explain long term equilibrium paths. Mostly the general case of stationarity with a time trend is applied. Thus the equilibrium path has an additional positive or negative (linear) trend. Contrary to this concept we have the concept of non-stationarity with integrated processes. That means that the process considered has no stable equilibrium path. Below we discuss these concepts and present methods to differ between both.

3.1 Trend Stationary Processes vs. Integrated Processes

In terms of econometrics a trend stationary process is defined as

$$y_t = \mu + \gamma t + u_t$$

(1)

This model consists of an intercept $\mu$, a time-dependent growth path $\gamma t$ and the residual $u_t \sim N(0, \sigma^2)$. A stationary process follows an equilibrium path and it is independent of time index $t$. A stationary process has a finite and constant mean $\mu$ and a finite and constant variance $\sigma^2$ for all observations t. Furthermore there must be a constant covariance for $y_t$ and $y_{t+k}$ for all $t$ depending on $k$ only.
After detrending the process (1) fulfills the properties of a stationary process.\textsuperscript{13}

Innovations have permanent effect if there is no stable equilibrium path. In this case we may have a random walk process or a random walk process with drift.\textsuperscript{14}

\[ y_t = \mu + \gamma t + \sum_{i=1}^{t} u_{t-i} + u_t \]  

(2)

In this case we also have an intercept $\mu$ and a time trend $\gamma t$ but detrending does not lead to a weak stationary process. The residual $u_t$ is $N(0, \sigma^2)$ distributed. Contrary to the stationary model with time trend we call the time dependent component of an integrated process drift. A random walk process has an infinite variance in contrast to a stationary process. These processes are called integrated processes because the first difference of such a process is conform to stationarity.

\[ \Delta y_t = \gamma + u_t \]  

(3)

3.2 Stationary Models and Structural Breaks

In the past empirical economic analysis handeled time series as nonstationary or integrated processes if standard unit root tests failed.\textsuperscript{15} Perron (1989) propose a trendstationary model with structural break so that many of the former nonstationary processes fulfill properties of stationarity. A structural break can occur in the intercept, in the time trend or in both terms. Perron (1989) explains the structural breaks by exogenous occasions. Zivot and Andrews (1992) and Nunes et al. (1997) propose a method to estimate the breaks endogenous.

If we have a structural break then standard unit root tests fail. There are three different models with structural break to consider

\[ y_t = \mu_1 + \gamma t + (\mu_2 - \mu_1)D_{\mu} + u_t \]  

(4)

\[ y_t = \mu + \gamma_1 t + (\gamma_1 - \gamma_2)D_{\gamma} + u_t \]  

(5)

\[ y_t = \mu_1 + \gamma_1 t + (\mu_2 - \mu_1)D_{\mu} + (\gamma_1 - \gamma_2)D_{\gamma} + u_t \]  

(6)

First we have a break in intercept (4) that means dummy $D_{\mu} = 1$ if $t > T_B$. $T_B$ is the break point. Second we have a break in time trend (5). $D_{\gamma} = t - T_B$ if $t > T_B$. Finally we have a break in intercept as well as in time trend (6).

3.3 Unit Root Test

There are several unit root test procedures available. The most common is the augmented Dickey-Fuller test (ADF test). The ADF test is based on the DF test by Fuller (1976), Dickey and Fuller (1979, 1981) and Said and Dickey (1984). We

\textsuperscript{13}Hansen (1993), p.136

\textsuperscript{14}The name random walk derives from the infinite effect of stochastic innovations. A complete description of equilibrium models and the econometric implications is given by Engle and Granger (1991).

have a random walk process if the observation \( y_t \) in \( t \) is fully determined by \( y_{t-1} \). A unit root test shows whether \( \rho \) in

\[
y_t = \rho y_{t-1} + \varepsilon_t
\]

is equal to one. If so, we have a nonstationary model with a unit root.  

Usually we have a complex structure in the lags \( \varepsilon_t \). That means, (7) is not suited well to describe the real context. Generally we have

\[
y_t = \sum_{i=1}^{p} \rho_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t
\]

\( \varepsilon_t \sim N(0, \sigma^2) \). (8) is a general ARMA\((p,q)\) model. It can be formulated as ARMA\((p,d,q)\) if there are one ore more unit roots. That means the \( d \)th difference of that process is a stationary ARMA\((p,q)\) process. A proper formulation of (8) requires \( p \) the order of the autoregressive model and \( q \) th order of the moving average model. In most cases these values are not given. Simple unit root tests based on the assumption that \( p \) and \( q \) are given or that \( q = 0 \). In the ADF test the complex ARMA\((p,q)\) model is approximated by a simpler AR\((p')\) model. As bigger \( p' \) is chosen as better is the approximation. The basic ADF test has the form

\[
\Delta y_t = \mu + \gamma t + \beta y_{t-1} + \sum_{i=1}^{p'} \delta_i \Delta y_{t-i} + \varepsilon_t
\]

It is a test of the null hypothesis that \( y_t \) is nonstationary against the alternative hypothesis that \( y_t \) is stationary. Nonstationarity means that \( \beta \) in (9) is nonsignificantly different from zero. The significance of the estimator cannot be tested by a standard \( t \)-test. The used critical values of the ADF test are suggested by MacKinnon (1991).

There are three parameters to set: \( \mu \) the intercept, \( \gamma t \) the time-dependent component and \( p' \) to describe the lag structure. With \( \gamma t \) we can differ between a trend stationary model and a random walk process with drift. Most difficult is the determination of \( p' \). Said and Dickey (1984) propose a procedure to determine \( p' \)

\[
p' = k \sqrt{T}
\]

The parameter \( k \) is not explicitly given. Schwert (1987) gives a rule of thumb more or less

\[
p' = \text{int} \left( 12 \sqrt{\frac{T}{100}} \right)
\]

\( \text{int} \) computes the integer of the value in parenthesis. The factor 12 is used if we have monthly observations. Finally there is procedure to determine \( p' \) based on the

\[\text{null, nonstationary, ARMA\((p,d,q)\), ADF, \(\beta\), \(\delta_i\), stationarity, nonstationarity, critical values, MacKinnon (1991), trend stationary, random walk with drift, Said and Dickey (1984), Schwert (1987), rule of thumb, monthly observations, procedure.}\]

\[\text{[Nonstationary] random walk processes have one or more unit roots. Step by step subtraction of the innovations of such a process leads to } y_0 \text{ in } t = 0. y_0 \text{ is called root or unit root of the process.}\]

\[\text{[Pagan and Wickens (1989)]}\]
Akaike information criterion (AIC)\textsuperscript{18}

\[ AIC = \ln \sigma^2 + \frac{2p}{T} \]

Perron (1989) used the following method to specify \( p' \). He increased \( p' \) step by step until the \( t \)-statistic of the additional lag is less than 1.60. This lag is removed and the former case is accepted. The procedure makes sure that the lag structure is properly specified.

The number of lags the test increases by an increasing number of observations. Rather than a less complex lag structure leads a more complex structure in (9) to the assumption \( \beta = 1 \). That means vice versa that an inadequate lag structure leads to the wrong presumption of a stationary process. Thus, the value \( p' \) should be bigger to prevent the wrong classification of a random walk process as a trend stationary.\textsuperscript{19}

The unit root test in models with structural break is based on the ADF procedure. But there is an additional step to specify the residuals analyzed by ADF test. We use (4), (5) and (6) to get the residuals. The test equation is based on a modified DF procedure

\[ u_t = \rho u_{t-1} + \varepsilon_t \]  \hspace{1cm} (13)

Perron (1989) computes critical values for the \( t \)-statistic of \( \rho \). These critical values depend on the character of the break (intercept, time trend or both terms) and the relative breaking point \( \lambda \) whereas \( \lambda = T/T_B \). Perron (1989) gives a procedure close to that of Phillips and Perron (1988) as well as a procedure close to that of Said and Dickey (1984).

4 Data Analysis

4.1 Risk Measures

The analysis includes several aggregated time series for West Germany from January 1968 to December 1990. That seems to be a fairly long time ago. But in 1990 the German reunification was finished. Subsequently there started a lot of politi-cal and social adaptation processes in East Germany. In particular the different reference points concerning infrastructure and traffic safety standards in East and West Germany affected the traffic accident situation and thus the risk measures considered here. That means in terms of econometrics that the German reunification leads to several breaks in the risk measures which can not be modeled with the precision required. A proper analysis needs a sufficient database and a longer observation period for East and West Germany.

In addition to the risk measure (killed people in traffic accidents per population) used by Wilde (1994) we formulate some more measures to give a more detailed description of traffic accident risks. Some authors do not use the population as the

\textsuperscript{18}Hartung (1989), p.687.

\textsuperscript{19}Gerdtham and Löthgren (1999)
reference point by the traffic demand.\textsuperscript{20} Here we use the population as the reference point to make the results comparable to RHT by Wilde (1994).

In the following analysis we use the concept of stationarity as the econometric pendant of RHT. If RHT is valid we have to reject the null hypothesis of a unit root as well as a stable positive or negative time trend. Instead we have to adopt the alternative hypothesis of a stationary process with no time trend. The following risk measures will be analyzed:

1. killed people in traffic accidents per population (\textsc{todb})
2. severe injured people per accident with bodily damages (\textsc{sverpups})
3. light injured people per accident with bodily damages (\textsc{lverpups})

The first measure is the same as used by Wilde (1994). The number of killed and injured people contains car inmates as well as pedestrians and bicyclists. The processes are seasonal adjusted and the natural logarithm is computed.

4.2 Results – Part 1

The first risk measure \textsc{todb} is analyzed by simple ADF test. We include an intercept as well as a time trend in the test. That means we test the null of an integrated model with drift against the alternative of a trend stationary model. First we compute \( p' \) in (9) using the procedure by Schwert (1987). Thus we have 276 observations and so \( p' = 15 \).

Perform the ADF test in this way the time trend or the time trend and the intercept might be insignificant. If so then we remove these components and specify a new test. In the next steps we adjust \( p' \) using the procedure proposed by Perron (1989) as well as the AIC. Both procedures will be modified as follows. We adopt \( p'_{\text{max}} = 20 \) that makes sure a proper modeling of any autocorrelation. Then we decrease \( p' \) stepwise. Perron’s procedure is finished as soon as the last included lag has a \( t \)-statistic less than 1.60. This lag will be removed and the former case is adopted. The AIC procedure is finished when AIC become minimal. Time trend and intercept will be included if they are not removed in a former step.

In case of \textsc{todb} we cannot reject the null (non stationarity) at the 5\% level. But we have a significant time trend as well as a significant intercept. Using the Perron procedure and the AIC criterion we get \( p' = 18 \) and \( p' = 15 \) respectively. That means the results using the Schwert procedure are the same as the results using AIC. The rejection of a unit root for \textsc{todb} is independent of the used procedure to compute \( p' \). Furthermore we can show a significant negative trend for that risk measure. That means the number of killed people in traffic accidents per population decreases significantly in the long run.

\textsuperscript{20}Shannon (1986), Chi\'r\'inko and Harper (1993)
Table 1: Unit root test for TDPB

<table>
<thead>
<tr>
<th></th>
<th>SCHWERT</th>
<th>PERRON</th>
<th>AIC</th>
</tr>
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<tr>
<td>TDPB</td>
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<td></td>
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<tr>
<td>$\beta$</td>
<td>-0.286</td>
<td>-0.332</td>
<td>-0.286</td>
</tr>
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<td>$t$-Statistik</td>
<td>-3.743</td>
<td>-3.975</td>
<td>-3.743</td>
</tr>
<tr>
<td>krit. Wert (5%)</td>
<td>-3.428</td>
<td>-3.429</td>
<td>-3.428</td>
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<tr>
<td>$\mu$</td>
<td>0.967</td>
<td>1.125</td>
<td>0.967</td>
</tr>
<tr>
<td>$t$-Statistik</td>
<td>3.750</td>
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<td>3.750</td>
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<tr>
<td>$\gamma$</td>
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<td>-0.001</td>
<td>-0.001</td>
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<td>$t$-Statistik</td>
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<td>-4.132</td>
<td>-3.936</td>
</tr>
<tr>
<td>$p$</td>
<td>15</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

4.3 Results – Part 2

In this part we have to analyze the number of severe injured and the number of light injured people per accident with bodily damages. As we can see in the graphs there are breaks in both at the same time in August 1984. Simple ADF tests lead to the expected result of an unit root in both processes. Therefore we applicate a model with structural break. At that time in August 1984 there was a modification in legislation. A penalty of 40 DM was implemented for not using seat belts.

The type of the structural break is not predetermined. It might be a break in intercept ($\mu$), in time trend ($\gamma$) or in both terms ($\mu\gamma$). That leads to the following regressions

$$y_{t,\mu} = f(\mu, \gamma, D_\mu)$$

$$y_{t,\gamma} = f(\mu, \gamma, D_\gamma)$$

$$y_{t,\mu\gamma} = f(\mu, \gamma, D_\mu, D_\gamma)$$

$\mu$ and $\gamma$ are the overall intercept and the overall time trend respectively. $D_\mu$ and $D_\gamma$ describe the break in intercept and the break in time trend respectively. The results of the three estimations are represented in table 2.

In case of SVERPUPS we can adopt a model with structural break in intercept as well as in time trend. The dummy $D_\mu$ is insignificant in the model with break in intercept and time trend for LVERPUPS. But the dummy $D_\mu$ is significant in the model with break in intercept only for LVERPUPS as well as $D_\gamma$ in the model with break in time trend only for LVERPUPS. If there is in fact a trend stationary model with break for LVERPUPS we have to reject one of the simple models with break in intercept only or with break in time trend only. Both cannot be valid simultaneously as the result of the integrated model (break in intercept and trend) shows. We reject the simple model with break in intercept only for LVERPUPS because this break is insignificant in the integrated model. That means we adopt a model with break in time trend and intercept for SVERPUPS and a model with break in time trend only for LVERPUPS.

In the next step we have to analyze whether the residuals of the estimations computed follow a stable equilibrium path. That means we have to compute ADF tests for that residuals. The procedure equals that for TDPB in principle i.e. in some steps we adjust the lag structure with several methods. First we use the procedure by Schwert (1987). $\lambda^*_{max}$ in case of the procedure by Perron (1989) and in case of AIC is 20. The test regressions are specified with no intercept and no trend. These
Table 2: Regression results of the models with break in intercept, break in time trend and break in both terms (SVERPUPS and LVERPUPS)

<table>
<thead>
<tr>
<th></th>
<th>intercept.</th>
<th>time trend</th>
<th>intercept./trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SVERPUPS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>6.107</td>
<td>6.104</td>
<td>6.099</td>
</tr>
<tr>
<td>$t$-stat.</td>
<td>1573.28</td>
<td>1926.30</td>
<td>2030.32</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>-0.0009</td>
<td>-0.0009</td>
<td>-0.0008</td>
</tr>
<tr>
<td>$t$-stat.</td>
<td>-27.06</td>
<td>-35.62</td>
<td>-31.38</td>
</tr>
<tr>
<td>$D_\mu$</td>
<td>-0.092</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t$-stat.</td>
<td>-15.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$D_\gamma$</td>
<td>-0.0021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t$-stat.</td>
<td>-21.77</td>
<td></td>
<td>-14.26</td>
</tr>
</tbody>
</table>

|            |            |            |                 |
| **LVERPUPS** |            |            |                 |
| $\mu$      | 6.861      | 6.868      | 6.869           |
| $t$-stat.  | 1992.74    | 2804.38    | 2722.40         |
| $\gamma$   | -0.0002    | -0.0002    | -0.0002         |
| $t$-stat.  | -5.27      | -11.18     | -10.89          |
| $D_\mu$    | 0.057      |            | 0.0093          |
| $t$-stat.  | 10.73      |            | 1.937           |
| $D_\gamma$ | 0.0016     |            | 0.0015          |
| $t$-stat.  | 21.75      |            | 16.06           |

components are already considered in the estimations (14), (15) and (16). Table 3 contains the results of the ADF tests.

Table 3: ADF tests for the residuals of the estimations in table 2

<table>
<thead>
<tr>
<th></th>
<th>SCHWERT</th>
<th>PERRON</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SVERPUPS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>-0.630</td>
<td>-0.630</td>
<td>-0.630</td>
</tr>
<tr>
<td>$t$-Statistik</td>
<td>-4.730</td>
<td>-4.730</td>
<td>-4.730</td>
</tr>
<tr>
<td>krit. Wert (5%)</td>
<td>-4.18</td>
<td>-4.18</td>
<td>-4.18</td>
</tr>
<tr>
<td>$p$</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

|            |         |        |     |
| **LVERPUPS** |         |        |     |
| $\beta$    | -0.503  | -0.503 | -0.503 |
| $t$-Statistik | -3.877  | -3.877 | -3.877 |
| krit. Wert (5%) | -3.85   | -3.85  | -3.85  |
| $p$        | 15      | 15     | 15   |

We can reject the null of a unit root for both risk measures. Thus we can adopt the alternative of stationary model with structural break in intercept and time trend for SVERPUPS (figure 2) and structural break in time trend only for LVERPUPS (figure 3). In addition both measures have a significant overall time trend which is negative for both until the break in August 1984. The negative trend enforces for SVERPUPS and it turns to a positive trend for LVERPUPS. That means contrary to the severe injured people per accident with bodily damages the number of light injured rise after implementation of the penalty in August 1984. The number of severe injured drops immediately at a significant amount (break in intercept).
5 Summary

A verification of RHT requires stationary time series with no time trend. Stationarity means that the measure follows a long run equilibrium path. More relevant for validity of RHT might be that the risk measures do not have any significant positive or negative time trend. But these properties cannot be observed for the risk measures considered.

Contrary to RHT we can show that the number of killed people in traffic accidents per population (TODPB, the risk measure used by Wilde (1994)) drops in the observed period. In addition we can show that a compulsory safety measure (penalty for not using seat belts) leads to the usually expected results. These are in contrast to the predictions of RHT postulating no effects of such safety measures. First we have an overall negative trend in both measures until the implementation of the penalty. Second there is an enforcement in that negative trend for the severe injured per accident (SVERPUPS). That means we have significantly less severe injured people after that safety measure. Finally we can observe a move to light injuries expressed in the rise of the light injured people per accident (LVERPUPS).

We find little evidence only for RHT. After implementation of a new safety measure we can not observe any adaptation of human behavior in road traffic that shifts back the accident risk to the former level. In fact we have positive effects in the overall traffic accident risk due to such safety measures. Mandatory safety measures seems to be useful in that cases where road users do not realize the possible utility of a change in their (driving) behavior (e.g. voluntary use of a seat belt).
Figure 3: LVERPUPS, equilibrium path and residuals in the model with structural break

References


Speed, Traffic Cameras and Justice:
Lessons Learned in Victoria, Australia

Rob Reid Smith
Monash University, Australia

September 2000
In December 1987, 80 people died in road crashes in the Australian State of Victoria. It was the highest monthly total of road deaths since 1979 and in 1979 the annual road deaths in the State had been 847, way above the annual level of about 670 to 680 deaths that had been occurring on the roads in the early 1980s. The police were worried. After years of traffic safety measures, including the mandatory wearing of seat belts and the introduction of random breath testing, the numbers of road deaths had been reduced from the peak of 1061 in 1970. Now they were rising again and they rose further over the next two years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>669</td>
</tr>
<tr>
<td>1987</td>
<td>705</td>
</tr>
<tr>
<td>1988</td>
<td>701</td>
</tr>
<tr>
<td>1989</td>
<td>776</td>
</tr>
</tbody>
</table>

In January 1987, the newly formed government agency, Transport Accident Commission (TAC), had taken over from the State Insurance Office as the monopoly provider of personal injury insurance for road crash victims in Victoria. The previous scheme of personal injury compensation was operating at a loss and, in 1987, the TAC had inherited a negative solvency ratio of – 49.1%. The prospect of significant increases in road deaths had substantial political and financial costs.

In 1989, three government agencies cooperated to form a new road safety strategy that later became known as the Victorian model. In part driven by activist Ministers, Victorian Police and VicRoads implemented the strategy and the TAC provided extra funding and a tough commercial discipline.

### Victoria’s Road Safety Agencies

<table>
<thead>
<tr>
<th>Victoria Police</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic law enforcement</td>
</tr>
<tr>
<td>Crash Investigation</td>
</tr>
<tr>
<td>Crash reporting &amp; prosecution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VicRoads</th>
</tr>
</thead>
<tbody>
<tr>
<td>State road authority</td>
</tr>
<tr>
<td>Licensing &amp; registration</td>
</tr>
<tr>
<td>Manage road network</td>
</tr>
<tr>
<td>Coordinate road safety</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third party insurer</td>
</tr>
<tr>
<td>Public awareness &amp; advertising</td>
</tr>
<tr>
<td>Investor in road safety programs</td>
</tr>
</tbody>
</table>

Set out in the following table are the key programs, component elements and supports of the Victoria model of road safety. The model identified two high risk behaviours that were critical offences and amenable to new ways of using technology to implement high volume enforcement action by Victoria Police: a high volume, speed camera program, supplemented by patrol car intercepts, and a program of mobile breath testing stations, the ‘booze buses’, which were highly visible enforcement of the blood alcohol limit (0.05) when driving.
The Victoria model itself extends well beyond a focus on enforcement and certainly well beyond speed management by traffic cameras. However, that technology supported by public awareness campaigns does constitute about 50 percent of the infringement transactions in one of the two offences identified as most critical, ie excessive speed.

### The Victoria Model of Road Safety

<table>
<thead>
<tr>
<th><strong>Key Programs</strong></th>
<th><strong>Characteristics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Public awareness campaigns</td>
<td>High intensity use of mass media, using television as the locomotive medium because of its emotive, visual pulling power; focused messages on critical offences at full commercial standard; other media/sites back up the “Don’t do it” message with consistent images</td>
</tr>
<tr>
<td>• Enforcement</td>
<td>High profile, high volume enforcement activity against critical offences demonstrates the serious intent to change high risk behaviour on the roads</td>
</tr>
<tr>
<td>• Engineering</td>
<td>Road safety is one of the core programs of the roads agency and includes targeting of high risk locations: the elimination of ‘black spots’</td>
</tr>
<tr>
<td>• Education</td>
<td>Production and distribution of high quality road safety materials for use by teachers in primary and secondary schools, plus the ‘police in schools’ program</td>
</tr>
</tbody>
</table>

### Key Elements

<table>
<thead>
<tr>
<th><strong>Key Elements</strong></th>
<th><strong>Characteristics</strong></th>
</tr>
</thead>
</table>
| • All programs based on research | • Focus group testing of advertising messages, plus market research after every new campaign  
| | • Enforcement counter-measures assessed by independent research centre, plus independent assessment of enforcement technology  
| | • Road safety audits to assess high risk locations  
| | • Consultants for development of road safety education materials |
| • Cooperation between agencies | • Agreed focus on identified critical offences and coordination of targeted counter-measures to reinforce effectiveness  
| | • Production of the road safety calendar showing the coordinated programs for the next 12 months, plus suggestions for actions by local authorities |
| • Investment in road safety | The TAC invested about $300 million in partnerships with Victoria Police and VicRoads over the 10 years 1988/89 to 1997/98 and saved itself an estimated $960 million in claims payments. Its investments covered:  
| | • Commercial marketing of road safety, particularly on TV  
| | • Supply of high technology for the speed enforcement program and random breath testing on large scales  
| | • Road safety programs in schools coordinated by VicRoads  
| | • Research and evaluation of road safety initiatives by Monash University and market research companies  
| | • Black spot engineering works organised by VicRoads ($75 million over the two years 1993 and 1994) |

### Key Supports

<table>
<thead>
<tr>
<th><strong>Key Supports</strong></th>
<th><strong>Characteristics</strong></th>
</tr>
</thead>
</table>
| • Legislation supports high volume enforcement | • Responsibility on car owner for speed camera offences  
| | • Breath testing accepted as evidence of blood alcohol measurement  
| | • Substantial penalties for offending and recidivism  
| | • Administrative adjudication of fixed penalty infringement notices |
| • Court system supports high volume enforcement | • Computerised processing of fixed penalty infringement notices  
| | • Offenders must choose to have their offence heard by a court  
| | • Active follow-up of all sanctions |
| • Community and stakeholders support high volume enforcement | • Active marketing to stakeholder organisations, including the automobile association and medical and legal professional associations  
| | • Active monitoring and follow-up using talk back radio relating to the enforcement program |
The Results

The best results in recent years for the Victoria model in terms of the annual rate of improvement were in the early 1990s. After that, the lower numbers of road deaths more or less held at that level:

- In 1990, a 29% reduction in road deaths and a saving of 229 lives compared to 1989
- In 1992, a further large reduction of 21% in road deaths, a saving of 103 lives over 1991.
- From January 1990 to January 1993, a 34% reduction in injuries
- At 396 road deaths in 1992, there had been a reduction of 49% in the road toll in the three years between December 1989 and December 1992. The 1992 level of 396 deaths was the lowest absolute level by far in the previous 40 years; the previous lowest was 480 killed in 1953 at a time when there were far fewer vehicles on the road
- Monash University Accident Research Centre has estimated that the campaigns against excessive speed (both the public awareness advertising and the enforcement activity, particularly the high volume speed camera program) contributed about 30% to this result
- Clearly there was a change in the behaviour of the driving public as shown in the Victoria Police scatter diagrams that graphically demonstrate year on year the cumulative effect of scanning the speed of 2 million vehicles per month; ie in a statistical sense, scanning the speed of every vehicle in Victoria every six and a half weeks
- The message was getting out: “if you speed, you will be caught, fined and the fine will be enforced”
- The high volume speed camera program helped to push down the rate of deaths per 10,000 registered vehicles to very low levels by international standards: below the level of the Sweden and the UK as well as below the level of the United States – whereas, for 30 years Victoria had been above or a long way above the levels of those countries.

Fel! Ogiltig länk.

What Worked Well in Victoria

1. The rapid reduction in the number of deaths from road crashes and, albeit a lesser, reduction in injuries won community support for the road safety program and assured that politicians would continue allocating resources to it (also helped by the efficient collection of fines which made the speed camera component of the program revenue positive).

2. The development of a comprehensive road safety strategy in which the speed camera program was a part, an important part

   - The combination of high intensity public awareness campaigns and high volume enforcement and the coordinated scheduling of these counter-measures at particular periods: times of day, days of week, weeks of the year
   - The coordination between agencies to produce the road safety calendar of activities which showed who is doing what and when over six and twelve month periods.

3. The presence of a commercially focused government agency as an investor in road safety

   - Victoria's TAC had a commercially vested interest to reduce road trauma by investing in counter-measures and the specific initial interest to recover from a negative solvency position by increasing its own internal efficiency
   - The TAC insisted on the commercial discipline of an adequate return on all of its investments in road safety
• The TAC insisted on pre- and post evaluations, ie a business case for the proposal and an evaluation of the effectiveness of the investment after implementation.

4. Implementation of high volume enforcement

• The independence of analysis and certification: such as the initial research on the counter-measures by the university research centre and the independent technical testing and quality assurance (Victoria Police have lost less than 10 cases in over five million speed camera tickets issued since 1989)

• Establishment of operational procedures that genuinely identified road safety as the primary objective (ie not revenue raising); eg determining the appropriate volume of ‘camera site hours’ per month and the use of geographic information systems to map and locate enforcement sites for speed cameras against the historical data on crash rates

• Wining public support for the program even though the fines were substantial (more so initially than 10 years later)

• The improved productivity under the outsourced arrangements where, starting in November 1998, the contractor provides all of the technical equipment, including the camera cars, provides the camera operators and runs the operation. Prosecutability has increased from about 65% in 1996 to about 85% currently (back in 1992, the year of the highest volume of speed camera infringement notices issued, over 523,000, the prosecutability rate was only 37%).

5. Court system support

• The establishment of a system of administrative adjudication that enabled efficient processing of large volumes of fixed penalty infringement notices

• The development of performance measures to assess and track the clearance of infringement notices and the smooth change to outsourcing the administrative systems and support of the judicial function.

What Did Not Work Well

1. The early and massive rates of reductions in road deaths could not be sustained, nor even was there a steady small reduction relentlessly achieved year after year


• There has not been the redevelopment of the enforcement strategy to achieve some reductions in deaths year on year

2. Performance measurement of road safety, at least in the public presentation of it, remains too limited to “deaths from road crashes”

• From the perspective of the investor and of the community at large, the economic costs of injuries from road trauma are much greater than the deaths because the numbers are much larger

• Whether a crash causes a death or just an injury is highly a matter of chance

• It’s not clear how many of the single vehicle crashes in rural areas might be intentional, ie suicide

3. Prior to outsourcing the administrative support for fines collection from traffic infringement notices, there were inadequate and fragmented systems for tracking the enforcement of the penalties
Speed, Traffic Cameras and Justice: Lessons Learned in Victoria, Australia

• Although only a small proportion of the total fines imposed remained uncollected, over the years these fines amounted to hundreds of millions of dollars and became a political issue

Lessons Learned: Critical Success Factors in High Volume Enforcement

<table>
<thead>
<tr>
<th>Political Pre-conditions</th>
<th>Political: Post Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Need for a champion with the determination to change high risk behaviour at each of three key levels: ministerial; heads of relevant agencies; key operational manager in each agency</td>
<td>Effective marketing of the message; ie working with public opinion to change high risk behaviour</td>
</tr>
<tr>
<td>2. Existence of an appropriate institutional framework of legislation and regulations (or the political support to establish it): eg responsibility on the registered owner of the vehicle</td>
<td>Government and the responsible agencies committed to develop a strategy and plans that are measured against performance indicators</td>
</tr>
<tr>
<td>3. Commitment of sufficient funding by a self-interested agency</td>
<td>Government and the responsible agencies committed to improvement of performance and set targets</td>
</tr>
<tr>
<td>4. Extent of the crisis: if not enough people are being killed or injured, resources will not be allocated and there will be no change</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational Pre-conditions</th>
<th>Operational: Post Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Scale and scope of enforcement effort matter: ie operations which are too small or too fragmented impose significant difficulties</td>
<td>Accountability of agencies delivering road safety actions</td>
</tr>
<tr>
<td>6. Research-based counter-measures appropriate to the specific environment</td>
<td>Permanent vigilance regarding performance of the road safety strategy: ie auditing both the component elements and the whole strategy</td>
</tr>
<tr>
<td>7. Capacity to develop, and the implementation of effective policies, plans and procedures for high volume enforcement (there is the chance it could go massively wrong)</td>
<td>Effective costing of service provision and the establishment of performance indicators of service delivery</td>
</tr>
<tr>
<td>8. Commitment to win and maintain public support for the program (the depth of intervention necessary to change high risk behaviour can make this challenging in cultures with high value on personal freedom)</td>
<td></td>
</tr>
</tbody>
</table>
### Support Services Pre-conditions vs. Post Conditions

<table>
<thead>
<tr>
<th></th>
<th>Support Services Pre-conditions</th>
<th>Support Services: Post Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Legislative framework includes the responsibility on the registered owner of the vehicle; a structure of fixed penalty offences and deterrence of recidivism (e.g. demerit points; and an administrative adjudication system</td>
<td>Willingness to review legislative provisions and regulations from time to time</td>
</tr>
<tr>
<td>10</td>
<td>The justice system imposes effective sanctions, including financial penalties and there is an effective administrative system to ensure the sanctions are carried out</td>
<td>Effective administrative, organisational and information technology systems for tracking and ensuring the enforcement of sanctions; and the monitoring and minimisation of bad debt</td>
</tr>
<tr>
<td>11</td>
<td>Stakeholder groups, particularly those with mass membership or directly relevant professional experience are brought into the process of strategy development, policy review and broad planning</td>
<td>Maintenance of an active program to ensure continuing support from each of the key stakeholder groups, including within the enforcement agency, and also from the general public</td>
</tr>
</tbody>
</table>

### Looking Back on the Speed Camera Program: Views of an Interested Outsider

Speed cameras are used in many places. What was unusual at the end of the 1980s was the determination to use that technology at a high volume as an essential negative incentive to change drivers’ perception of risk and to couple that with the administrative means of enforcing the sanctions and all of this in conjunction with a high intensity advertising campaign highlighting the high risk behaviours. The highest monthly total of speed camera notices issued was over 70,000 in July 1991, but Victoria’s Traffic Camera Office had the capacity to issue and process 10,000 notices per day, every day if the three million drivers in the State failed to get the message.

The program evolved over time and what was impressive was the thoroughness of the concept, albeit not always implemented in every respect. Examples of the thoroughness on the enforcement side were the awareness within Victoria Police of the heavy burden of responsibility in the accuracy of procedures where the burden of proof was effectively reversed once the speed camera infringement notice was issued and the design of matching the location of camera sites to those places at the times of day and days of the week that the crash history of that area showed were the highest risk times.

Likewise with the advertisements; these started out as a means of road safety education, seen initially as probably temporary. But they won unprecedented success and the methodology of producing the advertisements, using focus groups, pre-and post production testing and market research after every new campaign was run, meant that the TAC rewrote the book on how to market road safety using the mass media – heavily focusing on the themes of “Speed Kills” and “If You Drink and Drive, You’re a Bloody Idiot”.

- TAC’s road safety advertising from the agency Grey Advertising won the Golden Lion at Cannes International Advertising Film Festival as early as 1991 and Gold Medals in New York in 1990 and 1991 and TAC campaigns won a Gold Lion at Cannes in 1997, the Best of Show Award at New York One and the Gold Clio Award in New York in 1997, the Grand Prix Loerie Award in South Africa in 1998, a Silver Award in Ireland in 1998, Mobius Advertising Award in the USA in 1998 and a Gold Award at the New York One in 1999.

- As well as winning Australian advertising awards, including Australian Commercial of the Year in 1998, the TAC road safety advertisements have consistently achieved unprecedented levels of recall across the community year after year.

The saving of lives and the avoidance of injuries are priceless, but many societies do put values on the costs of road trauma and the biggest economic returns are not the collection of cash fines from offenders, nor even the avoidance of hospital and medical costs for those who would have been injured, but for the changed behaviour of road users because of the program. The biggest returns are at the level of the whole...
society and come from the avoidance of the loss of production when people are prematurely withdrawn, permanently or temporarily, from the work force.

And, beyond all of the economic calculations, any program which lowers the risk of being out on the shared public space of the roads makes the society a better place.
Session 15 Modelling of Road Safety

Characterizing commercial vehicle safety in Montana
*Jodi L. Carson*

An analysis of urban road traffic safety in the city of Stockholm – the use of aggregate time-series models with the TRIO programme
*Göran Tegnér*

The potential of microscopic simulation in traffic safety and conflict studies
*Iisakki Kosonen*

A Network Disaggregate Model for Road risk Indicators
*Ruth Bergel*
ABSTRACT

Incident Management in Rural Areas

Incident management is most often disaggregated into five non-distinct function areas – detection and verification, motorist information, response, site management, and clearance. Incident management, which started in response to large urban area issues such as traffic congestion (efforts to improve the management of incidents have been taking place for nearly three decades in Chicago, Illinois) is now producing benefits in smaller municipalities and their respective rural areas. Benefits from a more managed response include improved safety for both motorists and responders, improved agency efficiency, improved public image, and reduced motorist delay.

As Intelligent Transportation Systems (ITS) continue to develop, the application of computer and communications technologies to improve incident management will become increasingly important. Existing technologies as well as emerging technologies show great promise for application in rural areas. Some, such as mayday systems, that combine automatic collision notification and vehicle location technologies, would almost uniquely benefit rural areas.

The successful transfer of incident management-related ITS concepts and technologies to smaller municipalities could be jeopardized if differences between urban and rural environments are not recognized early on. These differences arise not only in the motivation for improving incident management but also in how incident management operations are performed and what resources are available.

When “selling” options that improve incident management to rural travelers and stakeholders, it is important to understand the different motivations in urban and rural environments. Traffic congestion and consequent political pressures drive urban stakeholders. In smaller municipalities and rural areas, concerns over safety and limited resources prompt improvements (although, at times, congestion can be a motivator in rural areas). More specifically, rural responders are faced with resources that are stretched further and potentially limited expertise due to limited training opportunities. These issues respectively may lead to feelings of resentment toward urban area “deep pockets” and a limited understanding of the benefits of incident management.

A clear understanding of the challenges faced by smaller municipalities and their respective rural areas will help to ensure a successful application of incident management-related ITS technologies and concepts for everyone’s benefit. This paper describes incident management challenges unique to or affecting smaller municipalities and rural areas and discusses potential ITS technologies suitable for application. More specifically, this paper assumes a problem/solution type approach when discussing each of the five functional areas in incident management.
An analysis of Urban Road Traffic Safety in the city of Stockholm – The use of aggregate time-series models with the TRIO programme

By
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TRANSEK Consultants
Solna Sweden

Paper to be presented at the 11th International Conference:
TRAFFIC SAFETY OF THREE CONTINENTS,
10-11 September 2000, CSIR Conference Centre
Pretoria, South Africa
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1 Aim and Scope of the Study

There is not one single factor that determines the development of road accidents. Contrary, there exists a certain “pattern” that helps us to explain and understand how and why road accidents occur.

The traffic environment is changing all the time and humans adapt to new or altered circumstances. This study aims at capturing some of these determining factors and to explain the development of road accidents in a broader perspective. This DRAG-3 model for the city of Stockholm does not give all the answers. But, hopefully, it contributes to an enhanced understanding of “why” and “how much” road accidents occur.

In the DRAG-3 Stockholm Study, police-reported road accidents have been analysed from January 1970 to December 1998, i.e. a time series period of 348 months. A database of some hundred possible explanatory variables has been collected, of which some 40 variables are included in the forecasting model developed within this project.

This project was commissioned by the City of Stockholm Street Office with Mrs Ann Storkitt as the client co-ordinator and has been carried out by Ms Therese Gustafsson and Mr Janne Heningsson with Mr. Göran Tegné, all at Transek Consultants.

2 Conclusions

Road traffic accidents increases again after many years of reductions
During the last four years 1996-1999, the number of killed in road accidents has increased from 11 to 17 persons (+55 %) and the number of severely injured from 97 to 171 persons (+76 %).

Increased mobility contributes to more road traffic accidents
Many human outdoor activities involves traffic movement either motorised or as pedestrians or cyclists – and thus accidents.

- The number of road accident fatalities in the city of Stockholm is almost proportional to the increase in total employment in the Stockholm region.
Some identified important traffic accident relationships:
- Higher gasoline prices contribute to fewer road accidents through less traffic and lower speeds.
- Lower average speed within the city is an important traffic safety factor.
- New road and city highway is a powerful traffic safety measure.
- Darkness kills. Improved road and streetlights reduces the severe accidents.
- Improved road winter maintenance is another safety measure in Nordic countries like Sweden.
- More bicycle trips at today's level-of-service, induces more killed and more severely injured persons.
- The use of bicycle helmets is a cheap and efficient traffic safety measure.
- The increased use of city jeeps and other heavy passenger cars leads to more accidents and also to an increase in the severity of injuries.

A traffic accident forecast for the year 2015 for the city of Stockholm
The population in the county of Stockholm is estimated to grow by over 300,000 (+17%) from 1,78 million to 2,09 million inhabitants in 2015. Employment is calculated to grow even faster (or by 30 % or by more than 260,000 persons).
- A growing Stockholm region leads to 3 more road traffic fatalities annually.
- New city highways would reduce the severe injuries by 30 persons annually.
- Enhanced safer bicycle traffic demands powerful counter measures in the existing street network.
- A gradual reduction in the average speed by the car traffic by 1 % annually up to the year 2015 might cause 6 fewer fatalities and 17 fewer severe injuries, compared to constant speeds.
- A successive 1 % improved road and street illumination is forecasted to reduce the number of killed by 21 % or by 5 persons.

3.1 Accident rates in Stockholm – an international perspective

In an attempt to compare road safety on the international scene, we have chosen accident frequency in terms of the number of injured or killed per 1,000 vehicles among a selection of 28 countries. This accident rate is compared to the motorization rate in the figure below:

![Accident frequency and Motorization Rate in 1998](http://www.worldbank.org/data/wdi2000/pdfs/tab3_12.pdf)

The figure (N.B. in logarithmic scale) reveals the tremendous variety in road traffic safety levels – from 5 injured/killed persons per 1,000 vehicles, represented by Namibia and Sweden, up to Botswana and Armenia, with 94 and 347 injured/killed persons according to the World Bank statistics. The other striking impression is the total lack of correspondence between safety level and motorization level. Some countries show low accident rates in spite of a rather high motorization rate, mostly Western countries but also Israel and Korean Republic. Other countries suffer from rather high accident rates and a rather low motorization rate, such as Bangladesh, Botswana and Armenia. Sweden has 5 injured/killed persons per 1,000 vehicles and 468 cars per 1,000 inhabitant.
3.2 The Evolution of road Accidents in the City of Stockholm

The evolution in road traffic accidents during the last 28 years can be characterised by a substantial decrease in the fatal accidents and in the number of accidents with severely injured victims. In the figure below, the number of victims (fatal, severely and lightly injured persons) is illustrated in a logarithmic scale:

![Fatal and severe victims in the Stockholm road traffic 1970 - 1998](chart.png)

A positive record of a substantial reduction in the number of fatal (-76 %) and severely injured victims (-60 %) can be registered for the entire period 1970 – 1998. On the other hand the lightly injured – and thus also the total number of victims - has been almost constant over the last three decades.

However, there is a strong tendency towards a new increase in the number of fatalities and in the severely injured victims during the last three years.
The distribution of road traffic victims by mode category in 1999 is shown below:

Around two-third of all road traffic victims are car drivers or passengers, while pedestrians make up 13% and bicyclists 17% of all victims.

The total number of road accidents could be seen as a product of the accident risk (here defined as the number of bodily damages per million vehicle-kilometres) and the exposure (the total number of vehicle kilometres) as can be viewed below:
The accident risk has fallen dramatically from around 0.5 accidents with bodily damages per million vehicle-kilometres in 1970 to 0.227 in 1992.

However, since 1992 the accident risk is increasing again and it was recorded to be 0.256 in 1998. At the same time (1970 – 1998), the total exposure in terms of total vehicle production (AADT among gasoline and diesel vehicles) in the County of Stockholm increased rapidly or by 76 %.

This is the real challenge for traffic safety policy – to compensate with traffic safety measures for a gradual increase in urban (and national - international) mobility.

In the next section we define the structure of the DRAG-3 Stockholm Model.

4 The Structure of the DRAG Model for Stockholm

The DRAG-philosophy aims at creating an enhanced understanding of two aspects of mobility: the demand for road usage, and the complex interactions affecting road accidents. The notion is based on a three-step approach, risk exposure, accident rate and its severity. A data base has been created for the City an the County of Stockholm with a broad spectrum of explanatory variables, such as socio-economic factors, laws and regulations, road and public transport data, vehicle fleet data, climate data and other related information aiming at explaining the development of road traffic and road
accidents \textit{ex post}. A special statistical programme package, called \textsc{TRIO}\cite{trio} has been used in the analysis.

The demand model is estimated on aggregate time series data for the whole area (in this case Stockholm County). The idea is to explain both traffic volumes (vehicle kilometres, vkms) and road accidents by a wide spectrum of explanatory variables by exploiting the vast variation in the monthly data set. This technique is called DRAG and stands for: "\textit{Demand for Road use, Accidents and their Gravity}". and is developed by professor Marc Gaudry at the Transport research Centre at the University of Montreal in Canada.

\footnote{\textsc{TRIO} is a statistical programme package for multiple regression model estimation of \textit{dependent variables} of the types: level, share and probability. \textsc{TRIO} has been developed by Prof. Marc Gaudry at the Centre de Recherche sur les Transports (C.R.T.) at University of Montreal in Canada.}
4.1 The Functional Form

In TRIO a demand model function is specified as follows:

\[
\frac{y_t^{\lambda_y} - 1}{\lambda_y} = \beta_0 + \beta_k \sum \left( \frac{x_k^{\lambda_y} - 1}{\lambda_k} \right) + u_t
\]

where

- \( y_t \) = the dependent variable for month t
- \( \beta_0 \) = the constant term
- \( \beta_k \) = the estimated regression coefficient
- \( x_k \) = the independent variable \( x_k \)'s value for month t
- \( \lambda_k \text{ resp. } \lambda_y \) = the so-called lambda-parameters for the independent variable \( x_k \) and for the dependent \( y \)-variable, i.e. a scale factor also estimated on the data set and which transforms the model or to a certain mathematical form. As a special case, when lambda is = 1, you get a linear model, and if lambda is = 0, you get a logarithmic model. This transformation is called "Box-Cox" transformation.

and

\[
\begin{align*}
u_t &= v_t f \left( Z_t \right)^{\lambda_y}, \\
v_t &= \sum_{i=1}^{r} \rho_i \nu_{t-i} + \omega_t,
\end{align*}
\]

where

- \( Z_t \) = a vector of heteroskedastic variables
- \( u_t \) = the error term (the residual vector) depending on the heteroskedasticity
- \( v_t \) = the error term (the residual vector) which is assumed to be dependent in the auto-correlation of the model

and finally

- \( \rho_i \) = the so called auto-regressive (time lag) parameters, which are also estimated and carries information about the time lag in the model.
- \( \omega_t \) = the third stage vector of residuals

4.2 The DRAG Model and the TRIO Programme

In our application of the DRAG approach in the Stockholm City and region, the following time series models have been carried out on a monthly basis for the period 1970 - 1998:

- an EXPOSURE model of total road mileage (vehicle kilometres) for gasoline and diesel passenger cars
• a FREQUENCY model of total number of road accidents with personal injuries and deaths
• a SEVERITY model of the:
  - number of light injuries per road accident
  - number of severe injuries per road accident
  - number of fatal deaths per road accident.

Analogous DRAG-models have been carried out in Quebec, Canada, Germany, France, Norway and California, USA².

5 The Evolution of Explanatory Variables

One of our most important conclusions is that the augmented activity levels in the society contribute to an increase in the number of accidents. In the figure below, the development of some of the major explanatory factors for the period 1970 – 1998 is presented:

Employment and population in the County of Stockholm has increased by 16 % and 21.5% respectively. Only the road length has increased that slowly. Most other background factors show a more swift development. The number of vehicle kilometres produced has increased by 77 % and the number of cars in use by 67 %.

Congestion (measured as vehicle kilometres per kilometre of road) is now more than 50 % higher than in 1970. The price of petrol is also more than 50 % higher. The share of diesel trucks is also much higher (+65 %).

The share of highway kilometres has developed very fast (by 165 %), thus contributing to a reduction in the accident rate. Also the share of car-licence holders older than 65 years has increased substantially from a very small level.

Due to an improved economic welfare, the share of heavy passenger cars (“City Jeeps”) has fivefold during the last 28 years.

Most of these factors have a decisive impact on accident rates and their severity.

6 The DRAG-3 Stockholm Model Results

6.1 The Exposure Model of vehicle-kilometres

The first part of the composite model is the Exposure model. The model contains some 20 variables and performs rather well. The rapid development of total vehicle production (AAMT) was most pronounced between 1970 and 1989. A sharp economic recession in Sweden in the first part of the 1990’s reduced the car traffic, but it has increased during the recent years. Apart from a few years, the predicted magnitude of vehicle-kilometres corresponds well with the actual records, gathered form gasoline and diesel sales statistics.
The most important explanatory variables and their average elasticities are summarised in the table below:

Table 1: Impact on total road mileage from various factors. Elasticities 1998, Stockholm County

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Elasticity</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment activity</td>
<td>0.46</td>
<td>5.06</td>
</tr>
<tr>
<td>Parking restrictions</td>
<td>0.43</td>
<td>8.72</td>
</tr>
<tr>
<td>Cars in use per employed</td>
<td>0.42</td>
<td>5.46</td>
</tr>
<tr>
<td>New road links (dummy)</td>
<td>0.38</td>
<td>6.01</td>
</tr>
<tr>
<td>No. of workdays/month</td>
<td>0.38</td>
<td>3.60</td>
</tr>
<tr>
<td>Retail sales per employed</td>
<td>0.32</td>
<td>8.44</td>
</tr>
<tr>
<td>Rain and snowfall mm/month</td>
<td>0.004</td>
<td>0.50</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.002</td>
<td>6.36</td>
</tr>
<tr>
<td>No. of non-working days/month</td>
<td>0.031</td>
<td>-0.56</td>
</tr>
<tr>
<td>Vacation activity</td>
<td>-0.003</td>
<td>-3.13</td>
</tr>
<tr>
<td>Darkness (share of 18 hours/day)</td>
<td>-0.21</td>
<td>-7.03</td>
</tr>
<tr>
<td>No. of snowdays/month</td>
<td>-0.014</td>
<td>-1.22</td>
</tr>
<tr>
<td>Population per employed</td>
<td>-0.22</td>
<td>-4.09</td>
</tr>
<tr>
<td>Real gasoline price</td>
<td>-0.24</td>
<td>-7.79</td>
</tr>
</tbody>
</table>

No of observations                     | 348        |
Pseudo-R2 adjusted for d.f.            | 0.938      |
Log likelihood                          | -3466.54   

Elasticities in bold are significant at the 5 % level.
The model shows the 14 most influential factors affecting the total (gasoline and diesel) vehicle kilometre production. Employment, the size of the car park in use and the shopping activity have a rather strong impact on the vehicle-kilometres produced. Increased parking restrictions in the CBD area lead to an increase in the total mileage, due to more search traffic but probably also to a diversion of car traffic to peripheral shopping centres outside the CBD area. The non-employed part of the population is more inclined to use walk, bike and public transport modes; therefore they use the private car less.

A 10% increase in the gasoline price reduces the road traffic volumes by 2.4%. Darkness and bad weather also reduces the car traffic. This model (in all with 22 variables) “explain” about 94% of the total monthly variation in the data set.

6.2 The Accident Models of Personal Injuries and Fatalities

The accident risk and severity models estimated consists of four sub-models with the same set of explanatory variables.

The first sub-model explains the total number of accidents with personal injuries or deaths in the city of Stockholm 1970 – 1998:

As can be seen from the figure above the correspondence between estimated and observed number of accidents is high. Even for the sub-model of severe victims, the correspondence is quite well between observed and estimated number except for a few years (1973, 1977, 1984).
Notice the increase in the number of severely injured during the last three years.

![Graph of Estimated and observed number of severe victims 1970 - 1998 in the city of Stockholm](image)

The number of fatalities is much lower and it has also been reduced substantially over time – from some 70 persons in 1970 to less than 20 persons in the late 1990’s:

![Graph of Estimated and observed number of fatalities 1970 - 1998 in the city of Stockholm](image)

The rate of randomness in how many killed victims that would occur from traffic accidents is naturally higher, which leads to a higher discrepancy between the observed and estimated numbers. However, even for this smaller group of severity, the correspondence between the DRAG-model and the reality is striking. The peaks in the years 1984 and 1989 are well represented, as well as the periods of decline and augmentation.
Exposure and economic activities

The number of personal accidents seems not to be proportional to the exposure in terms of vehicle-kilometres driven. An elasticity on the number of road accidents with personal injuries of 0.3 due to the number of vehicle kms, is found. A corresponding vehicle-kilometre elasticity on the number of killed victims amounts 0.60, i.e. a 10 % increase in road traffic yields 3 % more road accidents in Stockholm and 6 % more fatalities.

In the urban environment, it seems as if the share of diesel vehicles (in terms of mileage) reduces the number of accidents and their severity. Maybe, it slows down the overall traffic speed and also indicates a larger proportion of experience drivers.
Employment and vacation activities increase the number of road accidents with personal injuries, and the number of fatalities from these accidents becomes more frequent, when employment activities increases. Shopping activities seem to reduce both the number of road accidents, as the fatalities, while the number of severely injured increases.

The most striking results, however, stems from the observed number of bicyclists in the Stockholm City. A 10 % more frequent bicycle traffic, seem to lead to 2,4 % more road accidents, 3,0 % more severely injured and to 1,7 % more killed persons.

Vehicle fleet quality
Bad cars, i.e. cars with a higher proportion of remarks from the inspections, reduce the number of accidents (probably due to risk compensation behaviour), but increase the number of severely injured persons. The frequency of brake defects seem to lead to a more cautious driver behaviour, and thus, to a reduction in both the severe injuries and the number of killed victims. However, there exists a lot more vehicle quality factors with an influence on accidents, but there is a lack of such data in this study.

Road network data
New road links slightly increase the number of accidents (probably due to higher speeds), but reduce severe injuries and fatal deaths substantially. New and better roads are thus safer than other roads. Also urban highways (motorways) contribute to a safer environment with fewer accidents and fewer severely injured persons. Speed limits on the primary road network with a reduction from 110 to 90 km/h reduce the number of accidents and also severe injuries. A reduction of the urban car speed is clearly also a very important safety measure. Better street lighting is an important – and maybe underestimated – safety measure. It increased the number of accidents due to the “risk compensation” of the drivers, but reduces the number of killed persons dramatically.

Weather data
Weather conditions do have a certain impact on accidents. The number of severe accidents seem to increase as temperature is higher than normal (more people exposed), as rain and snow limits the sigh for the drivers and also as sunlight is reducing the concentration from driving. A decrease in the number of accidents could be noticed as the first snow makes drivers more cautious, while “darkness kills”. Darkness has a strong negative impact on the number of accidents and their severity, which could be counter-balanced by more and better road and streetlights.

Intervention measures & driver characteristics
An increased use of seat belts has a significant positive impact on road safety with a reduced number of fatalities. The use of bicycle helmets is found to have a decisive impact on road safety – fewer killed victims, but more severely injuries and more accidents, probably from “risk compensation”. With a bicycle helmet, cyclists drive less safely, but the helmets save lives.
The age composition of the drivers also seems to be important. A larger proportion of younger drivers (less than 20 years of age) might cause more accidents and more severely injuries but fewer killed persons, while the opposite tend to be the case among the elderly drivers. A larger proportion of elderly drivers (here indirectly measured through the number of licence holders) seems to reduce the number of accidents and their severity, but to a substantial increase in fatal deaths. One explanation to this might well be that, when elderly people become involved in a road accident, they tend to be more severely injured due to already existing health problems.

**Prices**
The impact of real gasoline prices on accidents is twofold. First, it influences through the exposure – higher gasoline prices reduce the number of vehicle-kilometres driven. Second, its has an impact on accidents through lower speeds. *Fuel taxation* might thus be an underestimated traffic safety measure.

**Intoxication & pregnancy**
The use of medicine might have an impact on accident rates, according to our findings. Measured as the sales of prescriptions at pharmacists, there is a tendency towards more accidents as prescriptions sales augment, but less severe injuries. The results are not conclusive, but the use of drugs and medicine should be examined in more detail as a traffic safety problem.

We have also collected information about the amount of pregnant women between 18 and 44 years during their first three months of pregnancy. Pregnancy might correlate with more accidents and more light injuries, and less severe injuries. In our previous study for the entire urban area of Stockholm County, we obtained more severe injuries together with a higher rate of pregnancy. There is a need for more detailed disaggregate surveys to follow up on this matter.

In a special model variant we have tested the influence of alcohol consumption on accidents and their severity. As regards the number of accidents and the number of fatalities, we have obtained a J-shaped relationship. At low initial levels of alcohol consumption per vehicle-kilometre, accidents and fatalities *fall* as alcohol consumption increases (elasticity: -0,01 and -1,65, respectively). At higher initial levels of alcohol consumption per vehicle-kilometre, accidents and fatalities *rise* as alcohol consumption increases (elasticity: +0,005 and +0,61, respectively). These finding are well in line with the results of the famous Grand Rapids Study of 1964, in which a J-shaped relationship was discovered.

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3 "The role of the drinking driver in traffic accidents", Blutalkohol, Vol. 11 (supplement 1), 1974, av R.F: Borkenstein, R.P. Shumate, W.B. Ziel och R. Zylman, Indiana University, Bloomington, Indiana, USA
6.3 The Impacts from various Factors on Accidents and their Severity

As indicated in section 4.2 above, the impacts are calculated in terms of:

- The exposure (total vehicle kilometres for gasoline and diesel vehicles) (DR) or Demand for Road use
- The frequency of accidents (total number of road accidents with personal injuries and deaths) (A) or Accident risk
- The Gravity (G) or severity of accidents (number of light injuries, severe injuries and fatal deaths, respectively, all counted per road accident).

Together this makes up the DRAG-model.

A way to summarise the impacts of the 34 variables on the four sub-groups of accident frequency and severity, is to present a selection of the most interesting traffic safety measures in a table in terms of plus (+) and minus (-) composite effects, see below:

Table 3: The composite impact on accidents and their severity from a selection of 15 explanatory variables; the City of Stockholm

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of accidents</th>
<th>No of light injuries</th>
<th>No of severe injuries</th>
<th>No of fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>No. of cyclists</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cars in use</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>New roads</td>
<td>+</td>
<td>+</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>Urban highways</td>
<td>--</td>
<td>-</td>
<td>--</td>
<td>-</td>
</tr>
<tr>
<td>Traffic (veh.kms)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Street lighting</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Safety belt use</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Bicycle helmet</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Gasoline price</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>Speed 50 km/h street</td>
<td>--</td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Darkness</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Temperature</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Younger drivers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td>Elderly drivers</td>
<td>-</td>
<td>0</td>
<td>--</td>
<td>++</td>
</tr>
</tbody>
</table>

Nota bene: A double sign means an elasticity greater than 1.
The number of *cyclists* increases all the four accident parameters. The *car park* as well as the amount of *employed persons* also contributes to more accidents (except for severity). *New roads* corresponds to more accidents and light accidents, while the number of severe victims drops sharply, as the new roads generally are constructed as safer roads than the older ones. When the share of *urban highways (motorways)* rises, then all four kinds of accident parameters drops.

More *road traffic* leads to more accidents. A trade off from severe injuries to fatalities seems to be a consequence. Improved *street lighting* has an interesting impact. The first three accident parameters *increase*, probably due to a “risk compensating behaviour” among motorists. They compensate by driving faster compared to a situation with less illumination. However, the number of killed victims will be reduced almost proportional as the lighting is improved.

The use of *safety belts* among drivers saves lives and transfers fatalities into severe injuries instead. The use of *bicycle helmets* has the same structure as streetlights – they save lives, but the risk compensating behaviour tends to rise all the other three components of accidents. The *gasoline price* is a strong traffic safety measure as it reduces all the four components.

*Darkness* and higher *temperature* kills victims and the both have a devastating impact on all the four components of accidents. Urban *speed* increases in the vicinity of 50 km/h has an evident destructive impact on the severity of accidents. However, a higher speed reduces the number of accidents with personal light injuries, maybe due to a higher awareness of traffic conditions.

The composition of the driving population seems to influence the accident pattern. The reader should be aware of the fact that this database only covers the urban road environment. It is well known that *younger drivers* are much more involved in accidents than medium aged people. But it might be different in the urban scene; maybe the denser traffic conditions slow down inexperienced drivers more than in the rural areas. Anyhow, they cause more accidents and more both light and severe injuries even in Stockholm. The *elderly drivers* seem to drive more carefully, and thus they are less involved in accidents. But as accidents occur, the risk to be killed in such an accident is much higher, maybe due to their more fragile physical condition.
The following factors augment the number of fatalities per road accident in the city of Stockholm (elasticities for the 1990s):

The single factor, which dominates the influence on the increase of the number of fatalities, is the share of licence holders older than 65 years of age, with an elasticity of 3.0. However, this is the very same factor that diminishes the total number of road accidents. This might be explained by the fact that elderly people tend to be more severely injured when they meet with road accidents due to health reasons.

A 10% increase of the average speed in city roads doubles the number of fatal accidents, and the same relationship is shown for darkness.

Socio-economic factors such as increased employment, vacation activity and shopping activities increase indirectly the number of fatal accidents by their impact on the exposure (vehicle kms per month). Amongst these, the employment activity is predominant. The number of bicyclists also augments the risk of fatal accidents, 10% more bicycles result in 1.7% more fatal accidents.
The following factors diminish the number of fatalities per road accident in the city of Stockholm (elasticities for the 1990s):

The real gasoline price is a powerful means for safer road traffic. An increase of the real gasoline price by 10 % results, according to the model, in 20 % fewer fatalities. This effect is partly explained to the fact that expensive petrol diminishes the number of vehicle kms.

A greater share of young licence holders tends to reduce the number of fatal accidents. If the use of bicycle helmets is increased with 10 %, the number of fatalities is almost equally reduced. An improvement of the street illumination by 10 % or the share the total motorway length by 10 % diminishes the number of fatalities by 9 %.

7 A forecast for Road Traffic Accidents

As part of our project for the city of Stockholm, a set of forecasts of accidents and their severity has been carried out for the year 2015. An estimated population increase of more than 300,000 inhabitants from 1,78 to 2,09 million is one of the assumptions behind the forecasts. Employment is estimated to grow by 30 % and shopping activities by 37 %. The car park is assumed to grow by 18 % and the car traffic volume in the county of Stockholm by 26 % between 1998 and 2015. A lot of various scenarios have been analysed with the DRAG-3 Stockholm model.
A selection of the most important results is presented below:

This first illustration concentrates on accident frequency and the number of lightly injured persons. Four of the six scenarios ‘produce’ more accidents with personal injuries. This is primarily due to the “risk compensation” mechanism and – for the two activity scenarios (“Employment” and “Bicycle traffic growth”, respectively) due to more mobility in the road and street environment. An “improved road network” (8 % more road capacity in 17 years) and “increased petrol prices” both yield fewer accidents.

The high growth in the number of light injuries is offset by a substantial decrease in the number of severe injuries and fatalities, see the figure below:
The figure above is ranked according to the fatalities. Only the two first scenarios – “Population and employment activities” and “Bicycle growth” yield more fatalities. The other four scenarios ‘produce’ fewer fatalities. An improved road network, together with better street illumination, a speed decrease and more expensive petrol prices (higher fuel taxes) all work towards a much lower level of killed victims.

The absolute magnitude of the forecasted reduction levels should not be interpreted as the exact truth, rather as an indication of small, medium or large impacts.

One important conclusion from our study is that the universal trend towards growing urban environment in terms of population, employment and general activity and mobility increases tends to augment the number of accidents and their severity. Therefore, there is a strong need for efficient counter-balancing traffic safety measures to be introduced and implemented. The choice and selection of such safety measures ought to rely on a sound, broad and deep knowledge not only in the “direct impacts” on traffic safety, but also in the understanding of the behavioural responses among drivers and motorists.

Time series models based on good empirical monthly data from both accident records and a broad spectrum of explanatory variables, is a useful tool to reveal such relationships as well as risk compensation behaviour.

8 References


Tegnér, G. (1996). "Infrastructure-induced Mobility - Some Swedish Evidence", ECMT Round Table 105, OECD, Paris, 6-7 November,


## 9 Appendix

*Table 2: Many factors explain the evolution of personal road accident injuries in the City of Stockholm; Elasticities for 1998*

<table>
<thead>
<tr>
<th>Model</th>
<th>Road accidents with pers. Injures &amp; deaths</th>
<th>Light injuries per road accident</th>
<th>Severe injuries per road accident</th>
<th>Fatal deaths per road accident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
</tr>
<tr>
<td>Exposure &amp; economic activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle kms per month</td>
<td>0,291 (-0,29)</td>
<td>0,56 (1,28)</td>
<td>-0,96 (-1,25)</td>
<td>0,30 (0,22)</td>
</tr>
<tr>
<td>Vehicle kms(^2) per month</td>
<td>0,11 (0,28)</td>
<td>-0,25 (-1,26)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Share of diesel vehicle kms</td>
<td>-0,26 (-2,28)</td>
<td>-0,005 (-0,09)</td>
<td>0,19 (0,60)</td>
<td>-1,34 (-2,22)</td>
</tr>
<tr>
<td>Employment act./veh.km</td>
<td>+0,25 (1,04)</td>
<td>+0,006 (0,09)</td>
<td>-0,09 (-0,19)</td>
<td>0,88 (0,99)</td>
</tr>
<tr>
<td>Real retail sales/ veh.km</td>
<td>-0,12 (-1,63)</td>
<td>0,05 (1,87)</td>
<td>+0,28 (1,92)</td>
<td>-0,25 (-0,99)</td>
</tr>
<tr>
<td>Vacation activity/veh.km</td>
<td>0,06 (1,17)</td>
<td>0,01 (-1,82)</td>
<td>-0,13 (-0,93)</td>
<td>0,31 (1,21)</td>
</tr>
<tr>
<td>Vacation days ”per se”/veh.km</td>
<td>0,07 (0,89)</td>
<td>0,01 (1,05)</td>
<td>-0,23 (-1,13)</td>
<td>0,10 (0,26)</td>
</tr>
<tr>
<td>No of bicycles across CBD</td>
<td>+0,24 (7,72)</td>
<td>-0,02 (-1,58)</td>
<td>0,06 (-0,59)</td>
<td>-0,07 (-0,35)</td>
</tr>
<tr>
<td>Vehicle fleet quality</td>
<td>-0,47 (-2,51)</td>
<td>+0,30 (3,52)</td>
<td>-1,27 (2,01)</td>
<td>0,01 (0,01)</td>
</tr>
<tr>
<td>Share of car remarks of all inspected</td>
<td>-0,16 (-1,62)</td>
<td>0,02 (0,66)</td>
<td>-0,15 (-0,64)</td>
<td>-0,12 (-0,26)</td>
</tr>
<tr>
<td>Brake defects/car at inspection</td>
<td>0,28 (1,69)</td>
<td>-0,06 (-0,77)</td>
<td>-0,13 (-0,22)</td>
<td>-1,66 (-1,36)</td>
</tr>
<tr>
<td>Road network data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New road links opened</td>
<td>+ 0,57 (2,81)</td>
<td>0,05 (0,42)</td>
<td>-1,96 (-3,36)</td>
<td>-0,64 (-0,49)</td>
</tr>
<tr>
<td>(dummy variable) LAM 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New road link “per se”</td>
<td>-0,16 (-1,62)</td>
<td>0,02 (0,66)</td>
<td>-0,15 (-0,64)</td>
<td>-0,12 (-0,26)</td>
</tr>
<tr>
<td>Share of motorway length</td>
<td>-1,08 (-2,79)</td>
<td>+0,32 (1,47)</td>
<td>-2,10 (-2,11)</td>
<td>+0,19 (0,10)</td>
</tr>
<tr>
<td>Explanatory factors</td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
<td>Elasticity (t-value)</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Parking restrictions</td>
<td>-0.10</td>
<td>-0.01</td>
<td>+0.39</td>
<td>-1.08</td>
</tr>
<tr>
<td>(dummy variable)</td>
<td>(0.58)</td>
<td>(-0.11)</td>
<td>(0.74)</td>
<td>(-1.00)</td>
</tr>
<tr>
<td>Park. restrictions ”per se”</td>
<td>-0.05</td>
<td>-0.05</td>
<td>+0.10</td>
<td>+0.38</td>
</tr>
<tr>
<td>(dummy variable)</td>
<td>(-0.78)</td>
<td>(1.30)</td>
<td>(0.87)</td>
<td>(1.44)</td>
</tr>
<tr>
<td>Share of no of days with speed limit 110=&gt;90 km/h</td>
<td>0.01</td>
<td>+0.03</td>
<td>-0.19</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(1.30)</td>
<td>(-1.39)</td>
<td>(-0.66)</td>
</tr>
<tr>
<td>Speed in Stockholm city</td>
<td>-1.01</td>
<td>0.40</td>
<td>1.73</td>
<td>3.16</td>
</tr>
<tr>
<td></td>
<td>(-1.92)</td>
<td>(1.15)</td>
<td>(1.09)</td>
<td>(0.93)</td>
</tr>
<tr>
<td>Street light (in MWh) per street-km in Sthlm LAM 1</td>
<td>1.52</td>
<td>0.05</td>
<td>0.01</td>
<td>-2.43</td>
</tr>
<tr>
<td></td>
<td>(1.74)</td>
<td>(0.12)</td>
<td>(0.00)</td>
<td>(-0.49)</td>
</tr>
<tr>
<td><strong>Weather data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average temperature/ month</td>
<td>+0.00</td>
<td>-0.01</td>
<td>+0.19</td>
<td>+0.03</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(-0.89)</td>
<td>(2.08)</td>
<td>(0.20)</td>
</tr>
<tr>
<td>Rain &amp; snowfall/month</td>
<td>+0.03</td>
<td>-0.002</td>
<td>+0.01</td>
<td>-0.02</td>
</tr>
<tr>
<td></td>
<td>(1.92)</td>
<td>(-0.21)</td>
<td>(0.21)</td>
<td>(-0.17)</td>
</tr>
<tr>
<td>No of days with snow/ month</td>
<td>-0.01</td>
<td>+0.01</td>
<td>-0.01</td>
<td>-0.13</td>
</tr>
<tr>
<td></td>
<td>(1.45)</td>
<td>(1.80)</td>
<td>(-0.41)</td>
<td>(-2.29)</td>
</tr>
<tr>
<td>Share of sunlight per daytime</td>
<td>+0.11</td>
<td>-0.004</td>
<td>-0.006</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>(3.08)</td>
<td>(-0.22)</td>
<td>(-0.06)</td>
<td>(-0.70)</td>
</tr>
<tr>
<td>Dummy for month with 1st autumn snowfall</td>
<td>+0.01</td>
<td>+0.01</td>
<td>-0.003</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>(0.51)</td>
<td>(0.48)</td>
<td>(-0.41)</td>
<td>(0.46)</td>
</tr>
<tr>
<td>Share of daytime (18 hrs) with darkness</td>
<td>+0.33</td>
<td>-0.03</td>
<td>+0.14</td>
<td>+0.40</td>
</tr>
<tr>
<td></td>
<td>(5.18)</td>
<td>(-1.13)</td>
<td>(0.70)</td>
<td>(1.00)</td>
</tr>
<tr>
<td><strong>Intervention measures &amp; driver characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of seat belt/driver</td>
<td>+1.00</td>
<td>-0.18</td>
<td>+2.86</td>
<td>-0.18</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(-0.82)</td>
<td>(2.82)</td>
<td>(-0.09)</td>
</tr>
<tr>
<td>Use of bicycle helmet</td>
<td>+0.42</td>
<td>-0.10</td>
<td>+1.52</td>
<td>-1.37</td>
</tr>
<tr>
<td></td>
<td>(2.67)</td>
<td>(-1.16)</td>
<td>(3.46)</td>
<td>(-1.65)</td>
</tr>
<tr>
<td>Share of licence holders &lt; 20 years (national data)</td>
<td>0.41</td>
<td>-0.24</td>
<td>0.22</td>
<td>-1.58</td>
</tr>
<tr>
<td></td>
<td>(1.95)</td>
<td>(-2.34)</td>
<td>(0.36)</td>
<td>(-1.23)</td>
</tr>
<tr>
<td>Share of licence holders &gt; 65 years (national data)</td>
<td>-0.24</td>
<td>+0.22</td>
<td>-2.50</td>
<td>+3.25</td>
</tr>
<tr>
<td></td>
<td>(-0.59)</td>
<td>(1.05)</td>
<td>(-2.16)</td>
<td>(1.44)</td>
</tr>
<tr>
<td>Legal limit of intoxication</td>
<td>+0.11</td>
<td>+0.02</td>
<td>-0.18</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td>(2.68)</td>
<td>(0.89)</td>
<td>(-1.34)</td>
<td>(-0.24)</td>
</tr>
</tbody>
</table>
Table 2 continued

<table>
<thead>
<tr>
<th>Explanatory factors</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calendar data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of workdays/month</td>
<td>+0.49</td>
<td>-0.09</td>
<td>-0.10</td>
<td>-0.003</td>
</tr>
<tr>
<td></td>
<td>(1.63)</td>
<td>(-0.81)</td>
<td>(-0.13)</td>
<td>(-0.00)</td>
</tr>
<tr>
<td>No of other days/month</td>
<td>+0.34</td>
<td>-0.03</td>
<td>-0.32</td>
<td>+0.30</td>
</tr>
<tr>
<td></td>
<td>(-2.59)</td>
<td>(-0.71)</td>
<td>(-1.08)</td>
<td>(0.46)</td>
</tr>
<tr>
<td>Prices</td>
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<td></td>
</tr>
<tr>
<td>Real gasoline price</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAM 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No of pregnant women 1st 3 months</td>
<td>0.06</td>
<td>0.29</td>
<td>-1.28</td>
<td>-0.77</td>
</tr>
<tr>
<td></td>
<td>(0.41)</td>
<td>(3.70)</td>
<td>(-2.55)</td>
<td>(0.79)</td>
</tr>
<tr>
<td>No of sold prescriptions</td>
<td>0.14</td>
<td>-0.01</td>
<td>-0.07</td>
<td>-0.59</td>
</tr>
<tr>
<td></td>
<td>(1.28)</td>
<td>(-0.17)</td>
<td>(-0.24)</td>
<td>(-0.96)</td>
</tr>
<tr>
<td>Lambda 1- value for variables marked with &quot;LAM 1&quot; t-test</td>
<td>0.660</td>
<td>1.332</td>
<td>0.485</td>
<td>0.520</td>
</tr>
<tr>
<td></td>
<td>(4.41/-2.27)</td>
<td>(5.80/1.45)</td>
<td>(8.25/-8.75)</td>
<td>(6.18/-5.71)</td>
</tr>
<tr>
<td>Explanatory power - $R^2$</td>
<td>0.656</td>
<td>0.695</td>
<td>0.825</td>
<td>0.866</td>
</tr>
<tr>
<td>Log-Likelihood</td>
<td>-1398.50</td>
<td>382.09</td>
<td>538.58</td>
<td>1050.40</td>
</tr>
<tr>
<td>Parameters estimate, no.</td>
<td>35</td>
<td>35</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>No of observations</td>
<td>348</td>
<td>348</td>
<td>348</td>
<td>348</td>
</tr>
</tbody>
</table>

Nota Bene: To achieve an elasticity for the amount of light injuries, severe injuries or fatal deaths, sum the elasticity of the number of road accident (1st column with elasticities) with the elasticity for light, severe injury or fatal death, respectively (2nd, 3rd or 4th column, respectively); Example: Elasticity of the number of severe injuries with respect to new road links = 0.57 - 1.96 = -1.39.
An analysis of Urban Road Traffic Safety in the city of Stockholm – The use of aggregate time-series models with the TRIO programme

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TRANSEK Consultants
Solna Sweden

Paper to be presented at the 11th International Conference:
TRAFFIC SAFETY OF THREE CONTINENTS,
10-11 September 2000, CSIR Conference Centre
Pretoria, South Africa
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1 Aim and Scope of the Study

There is not one single factor that determines the development of road accidents. Contrary, there exists a certain “pattern” that helps us to explain and understand how and why road accidents occur.

The traffic environment is changing all the time and humans adapt to new or altered circumstances. This study aims at capturing some of these determining factors and to explain the development of road accidents in a broader perspective. This DRAG-3 model for the city of Stockholm does not give all the answers. But, hopefully, it contributes to an enhanced understanding of “why” and “how much” road accidents occur.

In the DRAG-3 Stockholm Study, police-reported road accidents have been analysed from January 1970 to December 1998, i.e. a time series period of 348 months. A database of some hundred possible explanatory variables has been collected, of which some 40 variables are included in the forecasting model developed within this project.

This project was commissioned by the City of Stockholm Street Office with Mrs Ann Storkitt as the client co-ordinator and has been carried out by Ms Therese Gustafsson and Mr Janne Heningsson with Mr. Göran Tegnér, all at Transek Consultants.

2 Conclusions

Road traffic accidents increases again after many years of reductions
During the last four years 1996-1999, the number of killed in road accidents has increased from 11 to 17 persons (+55 %) and the number of severely injured from 97 to 171 persons (+76 %).

Increased mobility contributes to more road traffic accidents
Many human outdoor activities involves traffic movement either motorised or as pedestrians or cyclists – and thus accidents.

➢ The number of road accident fatalities in the city of Stockholm is almost proportional to the increase in total employment in the Stockholm region.
Some identified important traffic accident relationships:
- Higher gasoline prices contribute to fewer road accidents through less traffic and lower speeds.
- Lower average speed within the city is an important traffic safety factor.
- New road and city highway is a powerful traffic safety measure.
- Darkness kills. Improved road and streetlights reduces the severe accidents.
- Improved road winter maintenance is another safety measure in Nordic countries like Sweden.
- More bicycle trips at today’s level-of-service, induces more killed and more severely injured persons.
- The use of bicycle helmets is a cheap and efficient traffic safety measure.
- The increased use of city jeeps and other heavy passenger cars leads to more accidents and also to an increase in the severity of injuries.

A traffic accident forecast for the year 2015 for the city of Stockholm
The population in the county of Stockholm is estimated to grow by over 300,000 (+17%) from 1,78 million to 2,09 million inhabitants in 2015. Employment is calculated to grow even faster (or by 30 % or by more than 260,000 persons).
- A growing Stockholm region leads to 3 more road traffic fatalities annually.
- New city highways would reduce the severe injuries by 30 persons annually.
- Enhanced safer bicycle traffic demands powerful counter measures in the existing street network.
- A gradual reduction in the average speed by the car traffic by 1 % annually up to the year 2015 might cause 6 fewer fatalities and 17 fewer severe injuries, compared to constant speeds.
- A successive 1 % improved road and street illumination is forecasted to reduce the number of killed by 21 % or by 5 persons.

3.1 Accident rates in Stockholm – an international perspective

In an attempt to compare road safety on the international scene, we have chosen accident frequency in terms of the number of injured or killed per 1,000 vehicles among a selection of 28 countries. This accident rate is compared to the motorization rate in the figure below:


The figure (N.B. in logarithmic scale) reveals the tremendous variety in road traffic safety levels – from 5 injured/killed persons per 1,000 vehicles, represented by Namibia and Sweden, up to Botswana and Armenia, with 94 and 347 injured/killed persons according to the World Bank statistics. The other striking impression is the total lack of correspondence between safety level and motorization level. Some countries show low accident rates in spite of a rather high motorization rate, mostly Western countries but also Israel and Korean Republic. Other countries suffer from rather high accident rates and a rather low motorization rate, such as Bangladesh, Botswana and Armenia. Sweden has 5 injured/killed persons per 1,000 vehicles and 468 cars per 1,000 inhabitant.
3.2 The Evolution of road Accidents in the City of Stockholm

The evolution in road traffic accidents during the last 28 years can be characterised by a substantial decrease in the fatal accidents and in the number of accidents with severely injured victims. In the figure below, the number of victims (fatal, severely and lightly injured persons) is illustrated in a logarithmic scale:

A positive record of a substantial reduction in the number of fatal (-76 %) and severely injured victims (-60 %) can be registered for the entire period 1970 – 1998. On the other hand the lightly injured – and thus also the total number of victims - has been almost constant over the last three decades.

However, there is a strong tendency towards a new increase in the number of fatalities and in the severely injured victims during the last three years.
The distribution of road traffic victims by mode category in 1999 is shown below:

<table>
<thead>
<tr>
<th>Mode Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>66%</td>
</tr>
<tr>
<td>Motorbike</td>
<td>4%</td>
</tr>
<tr>
<td>Bicycles</td>
<td>17%</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>13%</td>
</tr>
<tr>
<td>Total</td>
<td>34%</td>
</tr>
</tbody>
</table>

Around two-thirds of all road traffic victims are car drivers or passengers, while pedestrians make up 13% and bicyclists 17% of all victims.

The total number of road accidents could be seen as a product of the accident risk (here defined as the number of bodily damages per million vehicle-kilometres) and the exposure (the total number of vehicle kilometres) as can be viewed below:
The accident risk has fallen dramatically from around 0.5 accidents with bodily damages per million vehicle-kilometres in 1970 to 0.227 in 1992.

However, since 1992 the accident risk is increasing again and it was recorded to be 0.256 in 1998. At the same time (1970 – 1998), the total exposure in terms of total vehicle production (AADT among gasoline and diesel vehicles) in the County of Stockholm increased rapidly or by 76%.

This is the real challenge for traffic safety policy – to compensate with traffic safety measures for a gradual increase in urban (and national - international) mobility.

In the next section we define the structure of the DRAG-3 Stockholm Model.

4 The Structure of the DRAG Model for Stockholm

The DRAG-philosophy aims at creating an enhanced understanding of two aspects of mobility: the demand for road usage, and the complex interactions affecting road accidents. The notion is based on a three-step approach, *risk exposure, accident rate and its severity*. A data base has been created for the City an the County of Stockholm with a broad spectrum of explanatory variables, such as socio-economic factors, laws and regulations, road and public transport data, vehicle fleet data, climate data and other related information aiming at explaining the development of road traffic and road accidents.
accidents *ex post*. A special statistical programme package, called TRIO\(^1\) has been used in the analysis.

The demand model is estimated on aggregate time series data for the whole area (in this case Stockholm County). The idea is to explain both traffic volumes (vehicle kilometres, vkms) and road accidents by a wide spectrum of explanatory variables by exploiting the vast variation in the monthly data set. This technique is called DRAG and stands for: "*Demand for Road use, Accidents and their Gravity*", and is developed by professor Marc Gaudry at the Transport research Centre at the University of Montreal in Canada.

---

\(^1\) TRIO is a statistical programme package for multiple regression model estimation of dependent variables of the types: level, share and probability. TRIO has been developed by Prof. Marc Gaudry at the Centre de Recherche sur les Transports (C.R.T.) at University of Montreal in Canada.
4.1 The Functional Form

In TRIO a demand model function is specified as follows:

\[
\frac{y_t^{\lambda_t} - 1}{\lambda_t} = \beta_0 + \beta_k \sum \left( \frac{x_k^{\lambda_t} - 1}{\lambda_k} \right) + u_t
\]

where

- \( y_t \) = the dependent variable for month \( t \)
- \( \beta_0 \) = the constant term
- \( \beta_k \) = the estimated regression coefficient
- \( x_{kt} \) = the independent variable \( x_k \)'s value for month \( t \)
- \( \lambda_k_{r e s p \lambda_y} \) = the so-called lambda-parameters for the independent variable \( x_k \) and for the dependent \( y \)-variable, i.e. a scale factor also estimated on the data set and which transforms the model or to a certain mathematical form. As a special case, when lambda is = 1, you get a linear model, and if lambda is = 0, you get a logarithmic model. This transformation is called "Box-Cox" transformation.

and

\[
\begin{align*}
    u_t &= v_t f (Z_t)^{\omega_t}, \\
    v_t &= \sum_{i=1}^{\nu} \rho_i v_{t-i} + \omega_t,
\end{align*}
\]

where

- \( Z_t \) = a vector of heteroskedastic variables
- \( u_t \) = the error term (the residual vector) depending on the heteroskedasticity
- \( v_t \) = the error term (the residual vector) which is assumed to be dependent in the auto-correlation of the model

and finally

- \( \rho_t \) = the so called auto-regressive (time lag) parameters, which are also estimated and carries information about the time lag in the model.
- \( \omega_t \) = the third stage vector of residuals

4.2 The DRAG Model and the TRIO Programme

In our application of the DRAG approach in the Stockholm City and region, the following time series models have been carried out on a monthly basis for the period 1970 - 1998:

- an EXPOSURE model of total road mileage (vehicle kilometres) for gasoline and diesel passenger cars
- a FREQUENCY model of total number of road accidents with personal injuries and deaths
- a SEVERITY model of the:
  - number of light injuries per road accident
  - number of severe injuries per road accident
  - number of fatal deaths per road accident.

Analagous DRAG-models have been carried out in Quebec, Canada, Germany, France, Norway and California, USA.

5 The Evolution of Explanatory Variables

One of our most important conclusions is that the augmented activity levels in the society contribute to an increase in the number of accidents. In the figure below, the development of some of the major explanatory factors for the period 1970 – 1998 is presented:

---

Employment and population in the County of Stockholm has increased by 16% and 21.5% respectively. Only the road length has increased that slowly. Most other background factors show a more swift development. The number of vehicle kilometres produced has increased by 77% and the number of cars in use by 67%.

Congestion (measured as vehicle kilometres per kilometre of road) is now more than 50% higher than in 1970. The price of petrol is also more than 50% higher. The share of diesel trucks is also much higher (+65%).

The share of highway kilometres has developed very fast (by 165%), thus contributing to a reduction in the accident rate. Also the share of car-licence holders older than 65 years has increased substantially from a very small level.

Due to an improved economic welfare, the share of heavy passenger cars (“City Jeeps”) has fivefold during the last 28 years.

Most of these factors have a decisive impact on accident rates and their severity.

6 The DRAG-3 Stockholm Model Results

6.1 The Exposure Model of vehicle-kilometres

The first part of the composite model is the Exposure model. The model contains some 20 variables and performs rather well. The rapid development of total vehicle production (AAMT) was most pronounced between 1970 and 1989. A sharp economic recession in Sweden in the first part of the 1990’s reduced the car traffic, but it has increased during the recent years. Apart from a few years, the predicted magnitude of vehicle-kilometres corresponds well with the actual records, gathered from gasoline and diesel sales statistics.
The most important explanatory variables and their average elasticities are summarised in the table below:

Table 1: Impact on total road mileage from various factors. Elasticities 1998, Stockholm County

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Elasticity</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment activity</td>
<td>0.46</td>
<td>5.06</td>
</tr>
<tr>
<td>Parking restrictions</td>
<td>0.43</td>
<td>8.72</td>
</tr>
<tr>
<td>Cars in use per employed</td>
<td>0.42</td>
<td>5.46</td>
</tr>
<tr>
<td>New road links (dummy)</td>
<td>0.38</td>
<td>6.01</td>
</tr>
<tr>
<td>No. of workdays/month</td>
<td>0.38</td>
<td>3.60</td>
</tr>
<tr>
<td>Retail sales per employed</td>
<td>0.32</td>
<td>8.44</td>
</tr>
<tr>
<td>Rain and snowfall mm/month</td>
<td>0.004</td>
<td>0.50</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.002</td>
<td>6.36</td>
</tr>
<tr>
<td>No. of non-working days/month</td>
<td>0.031</td>
<td>-0.56</td>
</tr>
<tr>
<td>Vacation activity</td>
<td>-0.003</td>
<td>-3.13</td>
</tr>
<tr>
<td>Darkness (share of 18 hours/day)</td>
<td>-0.21</td>
<td>-7.03</td>
</tr>
<tr>
<td>No. of snowdays/month</td>
<td>-0.014</td>
<td>-1.22</td>
</tr>
<tr>
<td>Population per employed</td>
<td>-0.22</td>
<td>-4.09</td>
</tr>
<tr>
<td>Real gasoline price</td>
<td>-0.24</td>
<td>-7.79</td>
</tr>
<tr>
<td>No of observations</td>
<td>348</td>
<td></td>
</tr>
<tr>
<td>Pseudo-R2 adjusted for d.f.</td>
<td>0.938</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-3466.54</td>
<td></td>
</tr>
</tbody>
</table>

Elasticities in bold are significant at the 5% level.
The model shows the 14 most influential factors affecting the total (gasoline and diesel) vehicle kilometre production. Employment, the size of the car park in use and the shopping activity have a rather strong impact on the vehicle-kilometres produced. Increased parking restrictions in the CBD area lead to an increase in the total mileage, due to more search traffic but probably also to a diversion of car traffic to peripheral shopping centres outside the CBD area. The non-employed part of the population is more inclined to use walk, bike and public transport modes; therefore they use the private car less.

A 10% increase in the gasoline price reduces the road traffic volumes by 2.4%. Darkness and bad weather also reduces the car traffic. This model (in all with 22 variables) “explain” about 94% of the total monthly variation in the data set.

6.2 The Accident Models of Personal Injuries and Fatalities

The accident risk and severity models estimated consists of four sub-models with the same set of explanatory variables.

The first sub-model explains the total number of accidents with personal injuries or deaths in the city of Stockholm 1970 – 1998:

![Observed and estimated number of accidents with personal injuries 1970 - 1998 in the city of Stockholm](image)

As can be seen from the figure above the correspondence between estimated and observed number of accidents is high. Even for the sub-model of severe victims, the correspondence is quite well between observed and estimated number except for a few years (1973, 1977, 1984).
Notice the increase in the number of severely injured during the last three years.

The number of fatalities is much lower and it has also been reduced substantially over time – from some 70 persons in 1970 to less than 20 persons in the late 1990’s:

The rate of randomness in how many killed victims that would occur from traffic accidents is naturally higher, which leads to a higher discrepancy between the observed and estimated numbers. However, even for this smaller group of severity, the correspondence between the DRAG-model and the reality is striking. The peaks in the years 1984 and 1989 are well represented, as well as the periods of decline and augmentation.
Exposure and economic activities
The number of personal accidents seems not to be proportional to the exposure in terms of vehicle-kilometres driven. An elasticity on the number of road accidents with personal injuries of 0.3 due to the number of vehicle kms, is found. A corresponding vehicle-kilometre elasticity on the number of killed victims amounts 0.60, i.e. a 10 % increase in road traffic yields 3 % more road accidents in Stockholm and 6 % more fatalities.

In the urban environment, it seems as if the share of diesel vehicles (in terms of mileage) reduces the number of accidents and their severity. Maybe, it slows down the overall traffic speed and also indicates a larger proportion of experience drivers.
Employment and vacation activities increase the number of road accidents with personal injuries, and the number of fatalities from these accidents becomes more frequent, when employment activities increases. Shopping activities seem to reduce both the number of road accidents, as the fatalities, while the number of severely injured increases.

The most striking results, however, stems from the observed number of bicyclists in the Stockholm City. A 10 % more frequent bicycle traffic, seem to lead to 2,4 % more road accidents, 3,0 % more severely injured and to 1,7 % more killed persons.

Vehicle fleet quality
Bad cars, i.e. cars with a higher proportion of remarks from the inspections, reduce the number of accidents (probably due to risk compensation behaviour), but increase the number of severely injured persons. The frequency of brake defects seem to lead to a more cautious driver behaviour, and thus, to a reduction in both the severe injuries and the number of killed victims. However, there exists a lot more vehicle quality factors with an influence on accidents, but there is a lack of such data in this study.

Road network data
New road links slightly increase the number of accidents (probably due to higher speeds), but reduce severe injuries and fatal deaths substantially. New and better roads are thus safer than other roads. Also urban highways (motorways) contribute to a safer environment with fewer accidents and fewer severely injured persons. Speed limits on the primary road network with a reduction from 110 to 90 km/h reduce the number of accidents and also severe injuries. A reduction of the urban car speed is clearly also a very important safety measure. Better street lighting is an important – and maybe underestimated – safety measure. It increased the number of accidents due to the “risk compensation” of the drivers, but reduces the number of killed persons dramatically.

Weather data
Weather conditions do have a certain impact on accidents. The number of severe accidents seem to increase as temperature is higher than normal (more people exposed), as rain and snow limits the sigh for the drivers and also as sunlight is reducing the concentration from driving. A decrease in the number of accidents could be noticed as the first snow makes drivers more cautious, while “darkness kills”. Darkness has a strong negative impact on the number of accidents and their severity, which could be counter-balanced by more and better road and streetlights.

Intervention measures & driver characteristics
An increased use of seat belts has a significant positive impact on road safety with a reduced number of fatalities. The use of bicycle helmets is found to have a decisive impact on road safety – fewer killed victims, but more severely injuries and more accidents, probably from “risk compensation”. With a bicycle helmet, cyclists drive less safely, but the helmets save lives.
The age composition of the drivers also seems to be important. A larger proportion of younger drivers (less than 20 years of age) might cause more accidents and more severely injuries but fewer killed persons, while the opposite tend to be the case among the elderly drivers. A larger proportion of elderly drivers (here indirectly measured through the number of licence holders) seems to reduce the number of accidents and their severity, but to a substantial increase in fatal deaths. One explanation to this might well be that, when elderly people become involved in a road accident, they tend to be more severely injured due to already existing health problems.

**Prices**

The impact of real gasoline prices on accidents is twofold. First, it influences through the exposure – higher gasoline prices reduce the number of vehicle-kilometres driven. Second, its has an impact on accidents through lower speeds. Fuel taxation might thus be an underestimated traffic safety measure.

**Intoxication & pregnancy**

The use of medicine might have an impact on accident rates, according to our findings. Measured as the sales of prescriptions at pharmacists, there is a tendency towards more accidents as prescriptions sales augment, but less severe injuries. The results are not conclusive, but the use of drugs and medicine should be examined in more detail as a traffic safety problem.

We have also collected information about the amount of pregnant women between 18 and 44 years during their first three months of pregnancy. Pregnancy might correlate with more accidents and more light injuries, and less severe injuries. In our previous study for the entire urban area of Stockholm County, we obtained more severe injuries together with a higher rate of pregnancy. There is a need for more detailed disaggregate surveys to follow up on this matter.

In a special model variant we have tested the influence of alcohol consumption on accidents and their severity. As regards the number of accidents and the number of fatalities, we have obtained a J-shaped relationship. At low initial levels of alcohol consumption per vehicle-kilometre, accidents and fatalities fall as alcohol consumption increases (elasticity: -0,01 and -1,65, respectively). At higher initial levels of alcohol consumption per vehicle-kilometre, accidents and fatalities rises as alcohol consumption increases (elasticity: +0,005 and +0,61, respectively). These finding are well in line with the results of the famous Grand Rapids Study of 1964, in which a J-shaped relationship was discovered.

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3 “The role of the drinking driver in traffic accidents”, Blutalkohol, Vol. 11 (supplement 1), 1974, av R.F: Borkenstein, R.P. Shumate, W.B. Ziel och R. Zylman, Indiana University, Bloomington, Indiana, USA
6.3 The Impacts from various Factors on Accidents and their Severity

As indicated in section 4.2 above, the impacts are calculated in terms of:

- The exposure (total vehicle kilometres for gasoline and diesel vehicles) (DR) or Demand for Road use
- The frequency of accidents (total number of road accidents with personal injuries and deaths) (A) or Accident risk
- The Gravity (G) or severity of accidents (number of light injuries, severe injuries and fatal deaths, respectively, all counted per road accident).

Together this makes up the DRAG-model.

A way to summarise the impacts of the 34 variables on the four sub-groups of accident frequency and severity, is to present a selection of the most interesting traffic safety measures in a table in terms of plus (+) and minus (-) composite effects, see below:

Table 3: The composite impact on accidents and their severity from a selection of 15 explanatory variables; the City of Stockholm

<table>
<thead>
<tr>
<th>Impact on:</th>
<th>Factor</th>
<th>No. of accidents</th>
<th>No. of light injuries</th>
<th>No. of severe injuries</th>
<th>No. of fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Employment</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>No. of cyclists</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Cars in use</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>New roads</td>
<td>+</td>
<td>+</td>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Urban highways</td>
<td>--</td>
<td>-</td>
<td>--</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Traffic (veh.kms)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Street lighting</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Safety belt use</td>
<td>+</td>
<td>-</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bicycle helmet</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Gasoline price</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Speed 50 km/h street</td>
<td>--</td>
<td>-</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Darkness</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Younger drivers</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Elderly drivers</td>
<td>-</td>
<td>0</td>
<td>--</td>
<td>++</td>
</tr>
</tbody>
</table>

Nota bene: A double sign means an elasticity greater than 1.
The number of cyclists increases all the four accident parameters. The car park as well as the amount of employed persons also contributes to more accidents (except for severity). New roads corresponds to more accidents and light accidents, while the number of severe victims drops sharply, as the new roads generally are constructed as safer roads than the older ones. When the share of urban highways (motorways) rises, then all four kinds of accident parameters drops.

More road traffic leads to more accidents. A trade off from severe injuries to fatalities seems to be a consequence. Improved street lighting has an interesting impact. The first three accident parameters increase, probably due to a “risk compensating behaviour” among motorists. They compensate by driving faster compared to a situation with less illumination. However, the number of killed victims will be reduced almost proportional as the lighting is improved.

The use of safety belts among drivers saves lives and transfers fatalities into severe injuries instead. The use of bicycle helmets has the same structure as streetlights – they save lives, but the risk compensating behaviour tends to rise all the other three components of accidents. The gasoline price is a strong traffic safety measure as it reduces all the four components.

Darkness and higher temperature kills victims and the both have a devastating impact on all the four components of accidents. Urban speed increases in the vicinity of 50 km/h has an evident destructive impact on the severity of accidents. However, a higher speed reduces the number of accidents with personal light injuries, maybe due to a higher awareness of traffic conditions.

The composition of the driving population seems to influence the accident pattern. The reader should be aware of the fact that this database only covers the urban road environment. It is well known that younger drivers are much more involved in accidents than medium aged people. But it might be different in the urban scene; maybe the denser traffic conditions slow down inexperienced drivers more than in the rural areas. Anyhow, they cause more accidents and more both light and severe injuries even in Stockholm. The elderly drivers seem to drive more carefully, and thus they are less involved in accidents. But as accidents occur, the risk to be killed in such an accident is much higher, maybe due to their more fragile physical condition.
The following factors augment the number of fatalities per road accident in the city of Stockholm (elasticities for the 1990s):

![Factors increasing the number of fatalities in the city of Stockholm](image)

The single factor, which dominates the influence on the increase of the number of fatalities, is the share of licence holders older than 65 years of age, with an elasticity of 3.0. However, this is the very same factor that diminishes the total number of road accidents. This might be explained by the fact that elderly people tend to be more severely injured when they meet with road accidents due to health reasons.

A 10% increase of the average speed in city roads doubles the number of fatal accidents, and the same relationship is shown for darkness.

Socio-economic factors such as increased employment, vacation activity and shopping activities increase indirectly the number of fatal accidents by their impact on the exposure (vehicle kms per month). Amongst these, the employment activity is predominant. The number of bicyclists also augments the risk of fatal accidents, 10% more bicycles result in 1.7% more fatal accidents.
The following factors diminish the number of fatalities per road accident in the city of Stockholm (elasticities for the 1990s):

### Factors reducing the number of fatalities in the city of Stockholm

<table>
<thead>
<tr>
<th>Factor</th>
<th>Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real gasoline price</td>
<td>-2.00</td>
</tr>
<tr>
<td>Diesel vehkms</td>
<td>-1.60</td>
</tr>
<tr>
<td>Brake defects/car</td>
<td>-1.38</td>
</tr>
<tr>
<td>Share of lic. holders &lt; 20 years</td>
<td>-1.18</td>
</tr>
<tr>
<td>Parking restrictions</td>
<td>-1.08</td>
</tr>
<tr>
<td>Bicycle helmet use</td>
<td>-0.96</td>
</tr>
<tr>
<td>Illumination in MWh per street km</td>
<td>-0.90</td>
</tr>
<tr>
<td>Share of motorway length</td>
<td>-0.88</td>
</tr>
<tr>
<td>Share of lic. holders &gt; 20 years</td>
<td>-0.88</td>
</tr>
<tr>
<td>Diesel vehkms</td>
<td>-0.88</td>
</tr>
<tr>
<td>Brake defects/car</td>
<td>-0.88</td>
</tr>
<tr>
<td>Share of lic. holders &lt; 20 years</td>
<td>-0.88</td>
</tr>
<tr>
<td>Parking restrictions</td>
<td>-0.88</td>
</tr>
<tr>
<td>Bicycle helmet use</td>
<td>-0.88</td>
</tr>
<tr>
<td>Illumination in MWh per street km</td>
<td>-0.88</td>
</tr>
<tr>
<td>Share of motorway length</td>
<td>-0.88</td>
</tr>
<tr>
<td>Share of lic. holders &gt; 20 years</td>
<td>-0.88</td>
</tr>
</tbody>
</table>

The **real gasoline price** is a powerful means for safer road traffic. An increase of the real gasoline price by 10 % results, according to the model, in 20 % fewer fatalities. This effect is partly explained to the fact that expensive petrol diminishes the number of vehicle kms.

A greater share of **young licence holders** tends to reduce the number of fatal accidents. If the **use of bicycle helmets** is increased with 10 %, the number of fatalities is almost equally reduced. An improvement of the **street illumination** by 10 % or the **share the total motorway length** by 10 % diminishes the number of fatalities by 9 %.

### 7 A forecast for Road Traffic Accidents

As part of our project for the city of Stockholm, a set of forecasts of accidents and their severity has been carried out for the year 2015. An estimated population increase of more than 300,000 inhabitants from 1.78 to 2.09 million is one of the assumptions behind the forecasts. Employment is estimated to grow by 30 % and shopping activities by 37 %. The car park is assumed to grow by 18 % and the car traffic volume in the county of Stockholm by 26 % between 1998 and 2015. A lot of various scenarios have been analysed with the DRAG-3 Stockholm model.
A selection of the most important results is presented below:

This first illustration concentrates on accident frequency and the number of lightly injured persons. Four of the six scenarios ‘produce’ more accidents with personal injuries. This is primarily due to the “risk compensation” mechanism and – for the two activity scenarios (“Employment” and “Bicycle traffic growth”, respectively) due to more mobility in the road and street environment. An “improved road network” (8 % more road capacity in 17 years) and “increased petrol prices” both yield fewer accidents.

The high growth in the number of light injuries is offset by a substantial decrease in the number of severe injuries and fatalities, see the figure below:
The figure above is ranked according to the fatalities. Only the two first scenarios – “Population and employment activities” and “Bicycle growth” yield more fatalities. The other four scenarios ‘produce’ fewer fatalities. An improved road network, together with better street illumination, a speed decrease and more expensive petrol prices (higher fuel taxes) all work towards a much lower level of killed victims.

The absolute magnitude of the forecasted reduction levels should not be interpreted as the exact truth, rather as an indication of small, medium or large impacts.

One important conclusion from our study is that the universal trend towards growing urban environment in terms of population, employment and general activity and mobility increases tends to augment the number of accidents and their severity. Therefore, there is a strong need for efficient counter-balancing traffic safety measures to be introduced and implemented. The choice and selection of such safety measures ought to rely on a sound, broad and deep knowledge not only in the “direct impacts” on traffic safety, but also in the understanding of the behavioural responses among drivers and motorists.

Time series models based on good empirical monthly data from both accident records and a broad spectrum of explanatory variables, is a useful tool to reveal such relationships as well as risk compensation behaviour.

8 References


Tegnér, G. (1996). "Infrastructure-induced Mobility - Some Swedish Evidence”, ECMT Round Table 105, OECD, Paris, 6-7 November,


# Appendix

Table 2: Many factors explain the evolution of personal road accident injuries in the City of Stockholm; Elasticities for 1998

<table>
<thead>
<tr>
<th>Explanatory factors</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exposure &amp; economic activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle kms per month</td>
<td>0.291 (0.29)</td>
<td>0.56 (-1.28)</td>
<td>-0.96 (-1.25)</td>
<td>0.30 (0.22)</td>
</tr>
<tr>
<td>Vehicle kms(^2) per month</td>
<td>0.11 (0.28)</td>
<td>-0.25 (-1.26)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Share of diesel vehicle kms</td>
<td>-0.26 (-2.28)</td>
<td>-0.005 (-0.09)</td>
<td>0.19 (0.60)</td>
<td>-1.34 (-2.22)</td>
</tr>
<tr>
<td>Employment. act./veh.km</td>
<td>+0.25 (1.04)</td>
<td>+0.006 (0.09)</td>
<td>-0.09 (0.60)</td>
<td>0.88 (0.99)</td>
</tr>
<tr>
<td>Real retail sales/veh.km</td>
<td>-0.12 (-1.63)</td>
<td>0.05 (1.87)</td>
<td>+0.28 (1.92)</td>
<td>-0.25 (-0.99)</td>
</tr>
<tr>
<td>Vacation activity/veh.km</td>
<td>0.06 (1.17)</td>
<td>0.01 (1.82)</td>
<td>-0.13 (0.93)</td>
<td>0.31 (1.21)</td>
</tr>
<tr>
<td>Vacation days &quot;per se&quot;/veh.km</td>
<td>0.07 (0.89)</td>
<td>0.01 (1.05)</td>
<td>-0.23 (-1.13)</td>
<td>0.10 (0.26)</td>
</tr>
<tr>
<td>No of bicycles across CBD</td>
<td>+0.24 (7.72)</td>
<td>-0.02 (1.58)</td>
<td>0.06 (0.59)</td>
<td>-0.07 (-0.35)</td>
</tr>
<tr>
<td><strong>Vehicle fleet quality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of car remarks of all inspected</td>
<td>-0.47 (-2.51)</td>
<td>+0.30 (3.52)</td>
<td>-1.27 (-2.01)</td>
<td>0.01 (0.01)</td>
</tr>
<tr>
<td>Brake defects/car at inspection</td>
<td>0.28 (1.69)</td>
<td>-0.06 (-0.77)</td>
<td>-0.13 (-0.22)</td>
<td>-1.66 (-1.36)</td>
</tr>
<tr>
<td><strong>Road network data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New road links opened</td>
<td>+0.57 (2.81)</td>
<td>0.05 (0.42)</td>
<td>-1.96 (-3.36)</td>
<td>-0.64 (-0.49)</td>
</tr>
<tr>
<td>New road link &quot;per se&quot;</td>
<td>-0.16 (-1.62)</td>
<td>0.02 (0.66)</td>
<td>-0.15 (-0.64)</td>
<td>-0.12 (-0.26)</td>
</tr>
<tr>
<td>Share of motorway length</td>
<td>-1.08 (-2.79)</td>
<td>+0.32 (1.47)</td>
<td>-2.10 (-2.11)</td>
<td>+0.19 (0.10)</td>
</tr>
</tbody>
</table>
### Table 2 continued

<table>
<thead>
<tr>
<th>Explanatory factors</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking restrictions (dummy variable)</td>
<td>-0.10 (0.58)</td>
<td>-0.01 (-0.11)</td>
<td>+0.39 (0.74)</td>
<td>-1.08 (-1.00)</td>
</tr>
<tr>
<td>Park. restrictions &quot;per se&quot; (dummy variable)</td>
<td>-0.05 (-0.78)</td>
<td>-0.05 (1.30)</td>
<td>+0.10 (0.87)</td>
<td>+0.38 (1.44)</td>
</tr>
<tr>
<td>Share of no of days with speed limit 110=&gt;90 km/h</td>
<td>0.01 (0.22)</td>
<td>0.03 (1.30)</td>
<td>-0.19 (-1.39)</td>
<td>-0.16 (-0.66)</td>
</tr>
<tr>
<td>Share of no of days with speed limit 110=&gt;90 km/h</td>
<td>1.01 (1.92)</td>
<td>0.40 (1.15)</td>
<td>1.73 (1.09)</td>
<td>3.16 (1.09)</td>
</tr>
<tr>
<td>Street light (in MWh) per street-km in Sthlm LAM 1</td>
<td>1.52 (1.74)</td>
<td>0.05 (0.12)</td>
<td>0.001 (0.00)</td>
<td>-2.43 (0.93)</td>
</tr>
<tr>
<td>Weather data</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Average temperature/ month</td>
<td>+0.00 (0.01)</td>
<td>-0.01 (-0.89)</td>
<td>+0.19 (2.08)</td>
<td>+0.03 (0.20)</td>
</tr>
<tr>
<td>Rain &amp; snowfall/month</td>
<td>+0.03 (1.92)</td>
<td>-0.002 (-0.21)</td>
<td>+0.01 (0.21)</td>
<td>-0.02 (-0.17)</td>
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<tr>
<td>No of days with snow/ month</td>
<td>-0.01 (1.45)</td>
<td>+0.01 (1.80)</td>
<td>-0.01 (0.41)</td>
<td>-0.13 (2.29)</td>
</tr>
<tr>
<td>Share of sunlight per daytime</td>
<td>+0.11 (3.08)</td>
<td>-0.004 (-0.22)</td>
<td>-0.006 (-0.06)</td>
<td>-0.14 (-0.70)</td>
</tr>
<tr>
<td>Dummy for month with 1st autumn snowfall</td>
<td>+0.01 (0.51)</td>
<td>+0.01 (0.48)</td>
<td>-0.003 (-0.41)</td>
<td>-0.01 (0.46)</td>
</tr>
<tr>
<td>Share of daytime (18 hrs) with darkness</td>
<td>+0.33 (5.18)</td>
<td>-0.03 (-1.13)</td>
<td>+0.14 (0.70)</td>
<td>+0.40 (1.00)</td>
</tr>
<tr>
<td>Intervention measures &amp; driver characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of seat belt/driver</td>
<td>+1.00 (2.68)</td>
<td>-0.18 (0.82)</td>
<td>+2.86 (2.82)</td>
<td>-0.18 (-0.09)</td>
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<tr>
<td>Use of bicycle helmet</td>
<td>+0.42 (2.67)</td>
<td>-0.10 (-1.16)</td>
<td>+1.52 (3.46)</td>
<td>-1.37 (-1.65)</td>
</tr>
<tr>
<td>Share of licence holders &lt; 20 years (national data)</td>
<td>0.41 (1.95)</td>
<td>-0.24 (-2.34)</td>
<td>0.22 (0.36)</td>
<td>-1.58 (-1.23)</td>
</tr>
<tr>
<td>Share of licence holders &gt; 65 years (national data)</td>
<td>-0.24 (-0.59)</td>
<td>+0.22 (1.05)</td>
<td>-2.50 (-2.16)</td>
<td>+3.25 (1.44)</td>
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<tr>
<td>Legal limit of intoxication</td>
<td>+0.11 (2.68)</td>
<td>+0.02 (0.89)</td>
<td>-0.18 (-1.34)</td>
<td>-0.07 (-0.24)</td>
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Table 2 continued

<table>
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<tr>
<th>Explanatory factors</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
<th>Elasticity (t-value)</th>
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<td><strong>Calendar data</strong></td>
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</tr>
<tr>
<td>No of workdays/month</td>
<td>+0.49 (+1.63)</td>
<td>-0.09 (-0.81)</td>
<td>-0.10 (-0.13)</td>
<td>-0.003 (-0.00)</td>
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<tr>
<td>No of other days/month</td>
<td>+0.34 (-2.59)</td>
<td>-0.03 (-0.71)</td>
<td>-0.32 (-1.08)</td>
<td>+0.30 (+0.46)</td>
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<tr>
<td><strong>Prices</strong></td>
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<tr>
<td>Real gasoline price</td>
<td>-0.43 (-2.41)</td>
<td>0.15 (1.81)</td>
<td>-1.08 (-2.11)</td>
<td>-1.45 (-1.56)</td>
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<tr>
<td><strong>Intoxication &amp; pregnancies</strong></td>
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<td></td>
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<tr>
<td>No of pregnant women 1st 3 months</td>
<td>0.06 (0.41)</td>
<td>0.29 (3.70)</td>
<td>-1.28 (-2.55)</td>
<td>-0.77 (0.79)</td>
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<tr>
<td>No of sold prescriptions</td>
<td>0.14 (1.28)</td>
<td>-0.01 (-0.17)</td>
<td>-0.07 (-0.24)</td>
<td>-0.59 (-0.96)</td>
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<tr>
<td>Lambda 1- value for variables marked with“LAM 1” t-test 0;1</td>
<td>0.660 (4.41/-2.27)</td>
<td>1.332 (5.80/-1.45)</td>
<td>0.485 (8.25/-8.75)</td>
<td>0.520 (6.18/-5.71)</td>
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<tr>
<td><strong>Explanatory power - R²</strong></td>
<td>0.656</td>
<td>0.695</td>
<td>0.825</td>
<td>0566</td>
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<td><strong>Log-Likelihood</strong></td>
<td>-1398.50</td>
<td>382.09</td>
<td>538.58</td>
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<td><strong>Parameters estimate, no.</strong></td>
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<td>35</td>
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<tr>
<td><strong>No of observations</strong></td>
<td>348</td>
<td>348</td>
<td>348</td>
<td>348</td>
</tr>
</tbody>
</table>

Nota Bene: To achieve an elasticity for the amount of light injuries, severe injuries or fatal deaths, sum the elasticity of the number of road accident (1st column with elasticities) with the elasticity for light, severe injury or fatal death, respectively (2nd, 3rd or 4th column, respectively); Example: Elasticity of the number of severe injuries with respect to new road links = 0.57 - 1.96 = -1.39.
The Potential of Microscopic Simulation in Traffic Safety and Conflict Studies

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BACKGROUND

Traffic safety is a major problem in road traffic systems. Although the problems are serious it is difficult to study them systematically due to the fact the number of actual collisions is very small compared to the whole traffic flow and potential accident cases (conflicts). There is a growing interest to use computer simulation in order to tackle the problem systematically. Microscopic traffic simulation has been successfully used in evaluation of traffic efficiency and emissions, but not yet widely in studies of traffic safety aspects. This paper will discuss the potential of traffic safety simulation based on experiences from simulation studies in two research laboratories that were using very different types of traffic simulators.

TRANSIMS (Transportation Analysis and Simulation System) is a high-speed parallel micro simulator that allows simulation of large metropolitan areas on microscopic level. TRANSIMS was developed by the Los Alamos National Laboratory in New Mexico, USA. It utilizes synthetic populations to create the traffic demand and cellular automata for high-speed parallel simulation of traffic flows (Smith et al. 1995).

HUTSIM is a very different kind of microscopic simulator developed by the Helsinki University of Technology, Finland. The object-oriented HUTSIM model is built for very high precision simulation of interactions between vehicles, pedestrians, traffic environment and traffic control (figure 1). Because the high fidelity of modeling requires lot of computing power, very large networks cannot be simulated.

A common feature of TRANSIMS and HUTSIM is that they both use rule-based vehicle dynamics. In HUTSIM a set of few rules controls the selection of discrete speed levels and lanes (Kosonen 1999). In TRANSIMS also the space is discrete which leads to a very minimal and hence fast rule sets for control of speed and lane changing (Simon Nagel 1998).
MODELING TRAFFIC SAFETY

Using simulation for traffic safety studies is a complicated matter. Since the simulated traffic is usually collision free, the safety aspect is already built in to the model. In other words the simulated driving dynamics is derived from safety requirements and without any exceptions no accidents or even conflict situations will occur.

Two types of solutions can be used to allow safety studies with initially collision free simulator. One is to introduce some erroneous behavior to allow conflicts and accidents to take place. This approach has been used with HUTSIM as explained later. The other approach is to take the collision free driving dynamics as input to the safety model, which then assigns some probability of accident to each potentially risky driving situation. This type of approach was tested with the TRANSIMS system (Ree et al. 2000).

There are different levels of fidelity in modeling traffic systems. In macroscopic modeling no individual cars are identified and traffic is considered as a continuous flow. Therefore macroscopic simulation is not suitable for safety modeling and conflict studies between individual cars. With low fidelity microscopic simulators (like TRANSIMS), it is possible to model safety issues in rough level. The output of cellular automata must be postprocessed and filtered in order to achieve more realistic car behavior. High-fidelity microscopic models (like HUTSIM) offer plenty of possibilities for systematic examination of conflict situations between individual vehicles.

Figure 1. High-fidelity modeling of interactions with the object-oriented HUTSIM-simulator.
The most suitable model for traffic safety simulation is a so called nanoscopic model. This means very detailed modeling of driver perception, decision making and actions including possible limitations and errors within them (figure 2). A nanoscopic model gets very complicated, which requires a lot of computing power. This means that it is not possible to simulate all metropolitan traffic using nanoscopic simulator, as it is possible with low-fidelity models such as TRANSIMS. However, a nanoscopic model can also be used to feed driver behavior data to a micro simulator that runs faster.

![Figure 2](image_url) Nanoscopic modeling of driver behavior including various types of errors.

There are numerous factors that affect the driving performance, like age, experience, attitude, state of mind, alcohol/drugs etc. Various factors are discussed for example by Ledoux & Archer (1999). It is very difficult to include all these factors into a simulation model. However, if we assume a certain level and distribution of driver errors and reaction time, it is possible to simulate the consequences, i.e. what kind of conflict situations arise. It is also possible to examine how traffic flow, speed limit, traffic control, sight distances and complexity of the traffic environment affect the traffic safety. It is also most interesting to study the effects of ITS on traffic safety, especially when only part of the vehicles is equipped with certain devices while others are not (i.e. the effect of penetration rate of ITS-devices).

It is essential that the simulation model includes sufficient variance in the driver behavior. To produce risk situations some of the drivers must occasionally be inattentive, sleepy or disoriented. In micro simulation these things can be modeled as temporary lack of observation (short blackouts) and hence increased reaction times. The calibration and validation of such a simulation model is not an easy task, since many of the behavioral factors cannot be directly measured. One must especially study the real conflict situations and try to produce similar situations in the simulation model.
CONFLICT STUDIES USING HUTSIM

Recently a lot of interest has arised towards usage of micro simulation for traffic safety studies. This has led to several projects that are exploring the potential of simulation in traffic safety research. A research project called SINDI (Safety INDicators) was started in Sweden by the Royal Institute of Technology. The main objective is to produce reliable indicators of traffic safety especially for evaluation of the effects of ITS. A new simulator will be built based on HUTSIM micro simulator developed by Helsinki University of Technology. Similar project is also planned between Helsinki University of Technology and the Technical Research Centre of Finland.

New features and concepts are needed in the HUTSIM model in order to make it suitable for safety studies. Originally HUTSIM was developed for simulation of traffic in signalized intersections. The traffic model was then very deterministic producing very homogenous driving behavior. When HUTSIM was enhanced towards motorway simulation, more variation and distributions were added into the driving behavior. These features are also needed in the safety simulation since accidents and conflicts typically take place in exceptional situations i.e. in the tails of the distributions. Typical distributions needed are the distributions of the desired speed and reaction time as well as the minimum accepted gaps in car-following, lane changing and yielding.

In the HUTSIM model the drivers are characterized as calm or aggressive drivers between 0-99. The calm drivers tend to choose the low end of speed distributions and the high end of the gap distributions, while aggressive drivers tend to choose the opposite i.e. high speeds and short gaps. This arrangement gives sufficient variation in driving behavior while keeping consistency between adjacent choices of individual drivers.

Reaction time is an essential feature in traffic safety simulation. Typically in simulation models the reaction time is a constant value obtained by updating the vehicles in a certain order. In HUTSIM no updating order is presumed and the delay between an external event (like a pedestrian suddenly in front) and driver reaction is obtained in an other way. A human driver can react fast only if the emerging event is currently in his focus. However, usually the driver is sharing his focus with other things by scanning the mirrors, car equipment, traffic environment and traffic signs. The random delay caused by this scanning is modeled in HUTSIM by updating the driver perception/decision more rarely than the rest of the simulation model. Since the whole simulation model is typically updated every 0.1 second, any event that the driver should react to, can take place every so often. However if the driver decision is updated say once per second, then inherently a random reaction delay is generated between 0.0-1.0 seconds. In this models it is assumed that immediately after the first reaction to the external event, the driver turns to an attentive state where his perception and decisions are updated as often as the rest of the simulation model. However, after a given time of no events, the driver returns back to the “relaxed” mode where his reactions are delayed. To elaborate this model, the driver perception frequency could depend on the driver type.

A successful safety and conflict simulation requires modeling of two-way interactions between simulation agents like vehicle/drivers and pedestrians/cyclists. In the basic HUTSIM model yielding in intersections is performed by yield signs that show stop-signal when the gap is too small and go-signal when the gap is large enough. For each situation the critical accepted gap can be obtained from a distribution. However, in this model the vehicle with right of way never
reacts to the yielding vehicle (they have always go-signal). A modification was made recently to allow prioritized vehicles to react (decelerate) if the yielding vehicle is choosing a too small gap and hence causing a conflict situation. These conflict situations are detected and saved into data files for later analysis.

According to conflict analysis (Hydén 1987), the conflict situations can be divided into two portions (serious/non-serious) by experimentally studying the situations where drivers want to be and where not. Areas of serious/non-serious conflicts can be divided by a curved line in space of time to collision and speed. Also in simulation the speed and time to collision (ttc) can be registered at the first moment when the vehicle has to brake. This way a similar plot can be created that was obtained by the field studies. Also the severity of the simulated conflicts can then be classified based on experimental studies (curved line). Also the whole trajectory of vehicle deceleration can be demonstrated in the same way (figure 3.). This kind of approach is the first step towards systematic research of conflicts by using simulation model. If the number of conflicts in a given intersection can be evaluated, then it is quite simple to calculate an estimation of the number of accidents in the same intersection.

![Figure 3. Simulation of conflicts in a simple intersection (Y=Speed, X=TTC).](image)

A modified HUTSIM simulation model has already been used for preliminary safety studies. In the city of Helsinki the safety of pedestrian crossings has been studied by field measurements and by simulations. The simulation results confirmed the conclusion that reducing the speed limit in some critical intersections with high pedestrian volumes has very significant impact on the amount and severity of pedestrian accidents that are usually caused by a free vehicle.
HUTSIM has also been used for evaluation of some ITS-functions like ISA (Intelligent Speed Adaptation) and AICC (Automatic Intelligent Cruise Control). The simulations were made using a model from the ARENA-test site in Gothenburg, Sweden. The combination of ISA and AICC significantly reduced the number of severe pedestrian accidents as shown in figure 4.

These early trials demonstrate the potential of microscopic simulation in safety studies. However, as stated earlier it is important to elaborate the driver model with features that take in account errors in driver perception and reactions. The target is to combine HUTSIM with detailed nanoscopic driver model.

![Pedestrian - vehicle collision speed (case B) (ISA-vehicles with \( V_{\text{max}} = 40 \text{km/h} \))](image)

**Figure 4.** Simulation of pedestrian accidents with various penetration rate of ISA-control.

### ESTIMATING ACCIDENTS WITH TRANSIMS

In high speed simulation of large networks it is not possible to model the driver behavior in a very detailed way. In that case, rather than modeling accurately the driving dynamics and conflict situations, it is possible to use a low fidelity model and methods for estimating the accident probabilities. A more detailed presentation of the method discussed here is written by Ree et al., (2000).

The TRANSIMS traffic model is based on cellular automata (CA). In this model vehicles jump from one cell to another (7.5 meters long), hence the vehicle speed is always \( N \times 7.5 \text{ m/s} \). The speed levels are controlled by a set of rules. Another set of CA-rules is used to control lane changing and yielding in intersections (Nagel Schreckenberg 1992).
The CA-model produces rather rough speed trajectories, which have to be pre-processed for safety analysis (figure 5). TRANSIMS provides one snapshot output for every update. Therefore the speed and position of each vehicle can be obtained for every second. First the output file must be sorted to identify the individual speed trajectories. Then the CA speed trajectories must be low-pass filtered to produce more realistic driving behavior.

![Diagram of data flow](image)

**Figure 5. Computing accident likelihood from TRANSIMS simulation output.**

The next step is to find the deceleration events that can be potentially risky. For each deceleration event the required braking power is calculated (required to avoid collision). Also the time to collision can be calculated at the beginning of braking. It is assumed that these two factors can be used to estimate the probability of accident of any given braking situation.

The individual probabilities can be aggregated for each link over a given time interval like 15 minutes. These accident probabilities can be demonstrated with the TRANSIMS 3D visualizer. In figure 6 the development of accident probabilities are shown in a test network. The height of the bars indicates the accident probability while the colors are set according to the traffic densities.

After estimating the accident probabilities in each link, one can perform a monte-carlo simulation (roll the dice) to determine whether an accident really took place in any given link at given time interval. Also the actual accidents can be demonstrated by the 3D visualizer. Finally after the accidents have been generated a new microsimulation can be started where accident are actually generated. This way the effects of accidents to the city traffic can be studied.

Obviously external measurement data is needed to estimate the accident probability. Here a cumulative distribution of deceleration power was used. In this distribution low and moderate braking powers are most common. It is assumed that the rare events of high braking power are closely related to the high risk of accidents. It seems to be plausible that the low probability of braking power (rare events) correlates with high probability of accident. In accident simulation we are interested only in the rare events i.e. the tail of the distribution. We can assume that with low and moderate braking power the probability is close to zero. However, with high braking power we assume that \( P_{\text{coll}} = C(1-P_{\text{dec}}) \), where \( P_{\text{coll}} \) is the probability of accident for a braking
event, \(P_{dc}\) is cumulative probability of that braking power to take place and \(C\) is a constant value much less than one.

The basic assumption has not yet been fully proved, but we believe that the method is already consistent enough to provide reliable relative safety indicators. By tuning the parameters to match with actual number of accidents, the model will probably also predict reliable absolute number of accidents. So far the parameters are tuned to produce similar braking power distribution than the measured one, which is a good start.

![Figure 6. Demonstrating the simulated accident probabilities (height=probability, color=density).](image)

**CONCLUSIONS AND FURTHER RESEARCH**

Traffic safety simulation certainly seems to offer a lot of potential. However, after the first trials it is still early to state if it is going to be a real breakthrough in traffic safety research. It can be said for sure that microscopic simulation offers a good platform for systematic studies of conflict and accident situations. It is also very likely that good relative safety indicators can be produced to compare different traffic arrangements and environments. This includes also the assessment ITS with various types of in-vehicle equipment and each type with various penetration rates.
Safety related types of ITS that can be assessed with simulation include at least Intelligent Speed Adaptation (ISA), Automatic Intelligent Cruise Control (AICC) and collision warning systems.

Low-fidelity simulation combined with a separate accident estimation module seems to be relatively simple and efficient method for computing safety indicators. However, this method is likely to ignore many important factors that affect traffic safety, like driver perception and errors.

Nanoscopic modeling of driver behavior, perception and errors may offer an interesting research platform for testing various hypotheses of driver behavior. However, due to the very complex nature of the model it is unlikely that this type of model is going to be an everyday traffic planning tool very soon. It also depends on how fast the price of computing power is going down, since nanoscopic modeling in larger scale requires much more computing power than the present microscopic models.

A lot of further work is needed to enhance the HUTSIM simulation model for traffic safety assessment. In principle the present model can already be used for basic conflict studies by adding appropriate outputs for that purpose. Simulation of ITS from safety point of view requires modeling of the driver together with the supporting equipment. A nanoscopic driver model can be attached to the microsimulator as additional module that replaces the default vehicle control. It is also important to do intensive research of driving behavior especially in conflict situations to obtain realistic rules and distributions for the driver model.

REFERENCES

Acknowledgements. This research was supported by the National Interministerial Road Safety Observatory, and was made possible by funding from the DSCR under two contracts concluded between the Ministry of Public Works, the DIAM-Recherche association and INRETS. The authors would like to thank Bernard Girard (University of Paris-1, Panthéon-Sorbonne) for his contribution to the methodology, Patrick Le Breton (SETRA, the Technical Service for Road and Motorways studies) and Jean-Loup Madre (INRETS) for their contribution to the data constitution. Earlier versions of this research were presented in papers to the PTRC, which took place in Uxbridge, near London, in September 1997, and to the International Conference on "Road Accident Modelling Using the DRAG Approach" held in Paris in November 1998.
A network disaggregate model for road risk indicators
an explanatory and predictive approach

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Acknowledgements. This research was supported by the National Interministerial Road Safety Observatory, and was made possible by funding from the DSCR under two contracts concluded between the Ministry of Public Works, the DIAM-Recherche association and INRETS. The authors would like to thank Bernard Girard (University of Paris-1, Panthéon-Sorbonne) for his contribution to the methodology, Patrick Le Breton (SETRA, the Technical Service for Road and Motorways studies) and Jean-Loup Madre (INRETS) for their contribution to the data constitution. Earlier versions of this research were presented in papers to the PTRC, which took place in Uxbridge, near London, in September 1997, and to the International Conference on "Road Accident Modelling Using the DRAG Approach" held in Paris in November 1998.

1 INTRODUCTION

The risk modelling research using time series constructed on monthly data and over a long period, that we expose here, is designed to further the analysis of the development of road risk, by bringing together all the explanatory factors of risk and risk exposure that appear at an infra-annual rate.

The choice of monthly periodicity, which is the product of a compromise between the variability and availability of existing data and that of the determinants – weather and time-of-year conditions, traffic flow or its substitutes (economic activity, prices, and network development), behavioural variables and road safety measures – position this approach midway between the modelling of daily fluctuations and the modelling of long-term trends. After the focus of attention was shifted at the beginning of the 1990’s to monitoring short-term indicators in order to isolate a trend for local fluctuations, a need is now felt for an "explanatory" monitoring of risk indicators at a disaggregate level in relation to their principal determinants, for anticipation/prediction purposes.

Taking the recommendations of the COST 329 group as a basis, which point out the need of disaggregate models, we sought to develop a model for road risk data that focused on a
breakdown by type of road throughout France. It complements the TAG model that was constructed on French data at national level (Jaeger, Lassarre, 1998) and then utilised for international comparison purposes. Nevertheless we limited the number of determinants to about 10 for reasons of robustness, so the model is both explanatory and predictive.

We will present a version of the model limited to two types of network, main roads and toll motorways(*) and then also extended to the whole territory. We will first describe the structure of the model as a whole, and then go on to outline the main results: the outcome of tests of hypothesis related to econometric specification, the values for the indicators’ elasticities to their determinants, showing their development over the period, and the simulations carried out in the short term. Lastly, we will discuss these findings and suggest avenues of enquiry for continuing this research.

(*) In the first instance, we confined ourselves to the national road network (main roads and motorways), comprising 24,000 km of main roads and 7,000 km of motorways, which account for over one-third of France’s entire road traffic. The rest of the French network is composed of departmental roads, on the one hand, where the degree of severity is the greatest, and urban roads, on the other, where the accident rate is high. We thus have four distinct fields covering the whole of France and which present very different risk profiles within the overall road safety picture.

2. STRUCTURE OF THE MODEL

2.1. General Outline

Table 1: The structure of the model

<table>
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<th>Levels:</th>
<th>Risk exposure</th>
<th>Risk</th>
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<tr>
<td>Dependent variables</td>
<td>Traffic</td>
<td>Number of accidents (personal injury, fatal)</td>
<td>Number of victims (deaths, serious injuries, minor injuries)</td>
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<tr>
<td>Explanatory variables</td>
<td>Economic activity</td>
<td>Traffic</td>
<td>Economic activity</td>
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<tr>
<td></td>
<td>Use of seatbelt</td>
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<td>Use of seatbelt</td>
</tr>
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</table>

The approach adopted consists of constructing a model for the risk exposure-risk-severity triangle, taking account of explanatory factors and the search for an optimal functional form (Gaudry, 1984; Gaudry, Fournier, Simard, 1997).

The dependent variables of the three levels risk exposure/risk/severity are the traffic, the number of accidents and the number of deaths. We constructed a model for each of following networks: main roads, motorways and the whole territory as well.
2.2. The Data Base

The data base, compiled from monthly data for the 1975-1998 period, was created as part of the activities of an interministerial working party comprising representatives from SES, SETRA and INRETS. It is particularly informative as regards the main road and motorway networks, for which monthly mileage travelled is available, recorded by metres installed at different measuring points along the national road network.

It consists of:
- the numbers of personal injury accidents (fatal and non fatal) and victims (killed, seriously injured, slightly injured), broken down between four fields: main roads, motorways, departmental roads and urban roads, in built-up areas of over 5,000 inhabitants
- the data for kilometres travelled per month, on both main roads and toll motorways,
- data for transport supply: the length of the road network, fuel prices and motorway tolls,
- data for transport demand: gross domestic product, industrial production and household consumption;
- climatic variables relating to temperature, the occurrence of frost and the height of rain, which measure the average meteorological effect, for the whole month and the whole country,
- calendar variables
- behavioural variables: speed and seatbelt use on the basis of surveys, broken down by network.

Table 2: The data in 1998

<table>
<thead>
<tr>
<th></th>
<th>Main roads</th>
<th>Toll motorways</th>
<th>Public motorways</th>
<th>National network</th>
<th>Total network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic (10^8 vehkm)</td>
<td>886,28</td>
<td>595,15</td>
<td>373,81</td>
<td>1855,24</td>
<td>154,6</td>
</tr>
<tr>
<td>month. mean</td>
<td>43,86</td>
<td>50</td>
<td>31,15</td>
<td>about 1/3</td>
<td></td>
</tr>
<tr>
<td>Accidents</td>
<td>11 807</td>
<td>2 426</td>
<td>3 484</td>
<td>17 717</td>
<td>12 387</td>
</tr>
<tr>
<td>month. mean</td>
<td>984</td>
<td>202</td>
<td>290</td>
<td>1476</td>
<td>10 366</td>
</tr>
<tr>
<td>% total network</td>
<td>9.49%</td>
<td>1.95%</td>
<td>2.80%</td>
<td>14.24%</td>
<td></td>
</tr>
<tr>
<td>Deaths</td>
<td>1 928</td>
<td>341</td>
<td>130</td>
<td>2 399</td>
<td>8 437</td>
</tr>
<tr>
<td>month. mean</td>
<td>161</td>
<td>28</td>
<td>11</td>
<td>200</td>
<td>703</td>
</tr>
<tr>
<td>% total network</td>
<td>22.85%</td>
<td>4.04%</td>
<td>1.54%</td>
<td>28.43%</td>
<td></td>
</tr>
<tr>
<td>Network length (km)</td>
<td>24000</td>
<td>6646</td>
<td>2117</td>
<td>32763</td>
<td></td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>89</td>
<td>122</td>
<td>109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed excess (%)</td>
<td>50</td>
<td>40</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>seat belt use (%)</td>
<td>94</td>
<td>96</td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chart 1: Traffic on main roads (in hundreds of millions of vehicle-km)

Chart 2: Traffic on toll motorways (in hundreds of millions of vehicle-km)

Chart 3: Traffic on public motorways (in hundreds of millions of vehicle-km)
Chart 4: Accidents on main roads

Chart 5: Accidents on toll motorways

Chart 6: Accidents on public motorways
Chart 7: Deaths on main roads

Chart 8: Deaths on toll motorways

Chart 9: Deaths on public motorways
Chart 10: Total number of accidents

Chart 11: Total number of deaths
2.3. Economic Formulation

All the explanatory determinants of traffic volume, accident risk and accident severity are taken into account, including weather/time-of-year effects and those of an economic and behavioural nature, whether their impact is immediate or delayed for a few months. The variables are retained in the definitive model if they are regarded as statistically significant on the basis of a Student test.

We also formulate a strong hypothesis about the nature of the relationship that links each of these explanatory variables to the variable to be explained, and assume there is a multiplicative (Log-Log) relationship for the main explanatories (see chart 12), and a semi-multiplicative (Log-Lin) one for weather-related variables.

We nevertheless asked ourselves whether there might be non-constant elasticities and whether there might be interactions between the endogenous demand variables on the different networks, especially on main roads and motorways, which would reflect an effect of competition or complementarily and would show up on the risk and severity variables. These two questions are at the root of the research described here. The econometric specification that we are now going to outline is thus decisive for trying to give an answer.

![Chart 12: The number of accidents on toll motorways (log values) as a function of the number of the vehicle-km on toll motorways](image)

2.4. Econometric Specification

2.4.1 Univariate specification

The econometric formulation retained in the univariate approach is a multiple regression of a dependant variable Y on K explanatory variables Xk, with a functional form V and a
generalised structure of heteroskedasticity and autocorrelation of the residuals $u$, described as follows

$$
Y_i^{(a_k)} = \sum_{k=1}^{K} \beta_k X_k^{(a_k)} + u_i,
$$

$$
u_i = \sum_{k=1}^{p} \lambda_k u_{i-1} + w_i,
$$

$$\quad V_i \rightarrow V_i^{(\lambda)} = \begin{cases} 
\frac{V_i^{\lambda} - 1}{\lambda}, & \text{if } \lambda \neq 0 \\
\log V_i, & \text{if } \lambda = 0
\end{cases}
$$

The econometric formulation retained at the outset corresponds to the constraints $\lambda_y = 0$ and $\lambda_{X_k} = 0$ for the primary explanatory variables. We also looked for a more general functional form, while maintaining the constraint on the variable to be explained and freeing those relating to the primary explanatories. The test we conducted (cf. 3.1) does not enable us to reject the nullity constraint of the $\lambda_{X_k}$, from a strict statistical point of view.

2.5. Algorithm

The numerical results have all been obtained using the SAS software. We maximise the likelihood for a grid of $\lambda$ values. This likelihood is calculated for each value using a regression of the endogenous variable on the exogenous ones with auto-regressive remainders whose coefficients for the AR part are obtained stepwise (the SAS autoreg procedure, option m1). The likelihood is calculated using the Kalman filter and is optimised using the Gauss-Newton method.

3. THE RESULTS

3.1. Tests of Functional Form

Here we look for the optimal Box-Cox forms for a small number of exogenous variables, which are the primary explanatory variables. In the example of the model for the two networks, main roads and motorways, for which we have six equations, these exogenous variables are the two types of traffic on main roads and motorways for the equations of the two accident/severity levels and the determinants of traffic (final household consumption, fuel prices and the length of the motorway network) for the equations of the volume of traffic.

The object is to test whether, for these variables, there was a statistically significant difference between the estimated value of the vector of parameters $\lambda (\lambda_1, \lambda_2, \ldots, \lambda_K)$ – the vector thus has between one and three components, depending on the case – and the zero value $\lambda = 0$ initially retained (the logarithmic transformation retained in the RES), or the value $\lambda = 1$ (the linear form is sometimes retained). The results obtained are detailed in Table 3: The univariate models in estimated functional form, 1975-1993.

In any event, the test concluded that there was a statistically insignificant difference between the model obtained and the initial model. Conversely, the difference between the model obtained and a linear form model may be significant, and that is the case three times out of four for risk and severity equations. Hence, there is a risk of error if one accepts the linear form for the main exogenous variables in the risk and severity equations, but conversely one cannot reject the linear forms in equations for road demand.
At a statistical level, there is thus no significant difference between the model with Box-Cox transformations on the primary explanatory variables and the initial model. We can then turn to other criteria that might lead us to prefer one or other of the two cases in question. If the coefficients linked to the dynamics and impact of the exogenous variables do not vary much, there is a difference to be seen in the form of the endogenous variable's curve of elasticity to the exogenous variables, which is more general when a Box-Cox transformation is performed on the exogenous variables, and in the functional form itself that links the endogenous variable to the exogenous one.

To give an example, if one takes a value close to –2 for the Box-Cox parameter associated with household consumption (an explanatory factor behind motorway traffic), then the elasticity of household income to traffic is assumed to decline over time, falling from 0.5 in 1975 to 0.2 in 1992, whereas it is assumed to be constant and close to 0.4 if parameter \( \lambda \) is zero. As for the functional form linking traffic to household consumption, there is a long-term saturation effect in the first case that does not exist in the second.

3.2. Measuring Elasticities

The elasticities of explained variables are assumed to be constant in the initial model, whereas in the optimal model they are assumed to develop monotonously, growing or decreasing depending on whether the Box-Cox parameter has a positive or negative value, and as an example we detail the annual elasticity values obtained for 1975, 1984 and 1992 (see Table 3: The univariate models in estimated functional form, 1975-1993).

The elasticity values are consistent with those found in the literature on the subject. On French data, Madre and Lambert (1989) have estimated the annual traffic elasticities values, on main roads and motorways; new estimations have been proposed recently, by Bergel and Nespoux (2000).

The elasticities of traffic, the number of accidents and the number of fatalities to economic activity as measured by household consumption are positive and less than 1, the average being 0.3 over the period, but it can be seen that the separation of the two effects of consumption and the extension of the network, using a model based on two strongly correlated variables, can over-estimate the effect of extending the network, which is seen to average 0.7 over the period. The elasticity of traffic to fuel prices is more important on motorways than it is on main roads (the average being -0.2 and -0.4).

Fuel prices and the development of the motorway network appear to have an indirect effect on the numbers of accidents and fatalities through the intermediary of traffic. The elasticities of traffic to

The elasticities of the numbers of accidents and fatalities with respect to traffic are positive and less than 1, with an average value on the period that vary from 0.4 to 0.8 depending on the dependant variable and on the network.

Climatic variables generally have a lesser effect, except for the impact of temperature on the numbers of accidents and fatalities on the motorway network, which are twice as high in summer as in winter, the highest average value being 0.4 in the summer, for the number of deaths on motorways.
3.3. Short Term Approach

We also developed a short term approach, the objective being to restitute the trend of each dependent variables one to two years ahead. The more performing models are the models with log-log specification on filtered data (see Table 4). These final models take into account an atypical meteorological effect, as well as a calendar effect. By doing this, the average monthly error decreased about 10%.

As an example can be given by simulating the development of the total of accidents and the total of deaths for the two years 1998-1999 (see chart 13 and chart 14).

For each indicator, the real values were higher than the predicted values for the whole year 1998 (+1.8% and +4.3% for the number of accidents and the number of deaths). This still was the case in 1999 (+1.8% and +0.7%) and particularly for the number of accidents.

![Chart 13: The development of the total number of accidents for the period 1998-1999](image)

![Chart 14: The development of the total number of deaths for the period 1998-1999](image)
4. CONCLUSION

We will retain two types of conclusion.

The first one is the result thrown up by tests on the Box-Cox transformation: the logarithmic form cannot be rejected ($\lambda=0$ is accepted for the six equations), but nor can the linear form be accepted, at least not for the two levels of risk and severity ($\lambda=1$ is rejected in three out of the four equations of risk and severity). Given comparable quality, the model with Box-Cox transformation differs from the model with the logarithmic form in terms of the shape of the elasticity curves of the endogenous variable with respect to the main exogenous variables and in terms of the functional form itself, which may reveal saturation effects.

The second one is the need to use models with filtered data in order to restitute the trend in the short term. The log-log specification is also the best specification, considering the criterion of the mean average error.

The focus of this research is now on finding an interpretation of the models' functional forms, and this would mean the model-builder could choose between the different values for the Box-Cox parameters ($\lambda=0$, $\lambda$ estimated, $\lambda=1$), when they do not differ at a statistical level alone. The time-of-year effect remains to be integrated as well, and work to that end is under way. Above all, the way the behavioural variables, relating to speed excess and to seatbelt wearing, can also be taken into account, needs to be appreciated.

At the moment, the data base has been extended to the 1975-2000 period, and the model to the whole of the national road network, including the complete motorway network, and to all categories of accident (fatal/non fatal) and casualty (killed, seriously injured, slightly injured). It is being applied to the recent past so an analysis can be made of road safety performance in the beginning of 2000.

REFERENCES


Table 3: Models with estimated functional form on the main exogenous variables for the period 1975-1998

<table>
<thead>
<tr>
<th>Dynamics (*)</th>
<th>Traffic on toll motorways</th>
<th>Traffic on main roads</th>
<th>Traffic on toll motorways</th>
<th>Traffic on main roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(1)</td>
<td>-0.265</td>
<td>-0.471</td>
<td>-0.344</td>
<td>-0.344</td>
</tr>
<tr>
<td>A(2)</td>
<td>-0.518</td>
<td>-0.381</td>
<td>-0.209</td>
<td>-0.331</td>
</tr>
<tr>
<td>A(12)</td>
<td>-0.969</td>
<td>-0.976</td>
<td>-0.379</td>
<td>-0.552</td>
</tr>
<tr>
<td>A(14)</td>
<td>0.503</td>
<td>0.369</td>
<td>0.242</td>
<td>0.237</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exogenous variables (*)</th>
<th>Traffic on toll motorways</th>
<th>Traffic on main roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic on toll motorways</td>
<td>*** ***</td>
<td>-0.04</td>
</tr>
<tr>
<td>Traffic on main roads</td>
<td>-0.283</td>
<td>-1.333</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Final household consumption</th>
<th>-2.283</th>
<th>0.808</th>
</tr>
</thead>
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<tr>
<td>Fuel price</td>
<td>-0.087</td>
<td>1.424</td>
</tr>
<tr>
<td>Toll motorways' network length</td>
<td>-0.217</td>
<td>0.82 / 0.68 / 0.64</td>
</tr>
<tr>
<td>Rain</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Frost</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
<tr>
<td>Summer temperature</td>
<td>0.06</td>
<td>0.05 / 0.33 / 0.32 / 0.34</td>
</tr>
<tr>
<td>Winter temperature</td>
<td>-0.01</td>
<td>0.02</td>
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</table>

<table>
<thead>
<tr>
<th>Goodness of fit</th>
<th>Log likelihood</th>
<th>342,208</th>
<th>484,603</th>
<th>170,166</th>
<th>286,009</th>
<th>-65,111</th>
<th>170,851</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSE</td>
<td>0.661</td>
<td>0.182</td>
<td>2.935</td>
<td>1.053</td>
<td>23.544</td>
<td>2.917</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.405</td>
<td>0.349</td>
<td>0.686</td>
<td>0.331</td>
<td>0.455</td>
<td>0.27</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Tests on residuals</th>
<th>Sampling</th>
<th>accepted</th>
<th>accepted</th>
<th>rejected</th>
<th>accepted</th>
<th>accepted</th>
<th>rejected</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td>0.32</td>
<td>0.13</td>
<td>0.01</td>
<td>0.56</td>
<td>0.12</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Normality</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
<td>rejected</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
</tr>
<tr>
<td>0.76</td>
<td>0.99</td>
<td>0.54</td>
<td>0.0038</td>
<td>0.92</td>
<td>0.34</td>
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<td>White noise</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
<td>accepted</td>
</tr>
<tr>
<td>0.13</td>
<td>0.56</td>
<td>0.61</td>
<td>0.14</td>
<td>0.64</td>
<td>0.1</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Comparative tests</th>
<th>Sample (1/75 - 12/93)</th>
<th>209</th>
<th>209</th>
<th>209</th>
<th>209</th>
<th>209</th>
<th>209</th>
</tr>
</thead>
<tbody>
<tr>
<td>H0: lambda=0</td>
<td>LL0=340,468</td>
<td>LL0=484,233</td>
<td>LL0=170,118</td>
<td>LL0=285,942</td>
<td>LL0=65,416</td>
<td>LL0=169,615</td>
<td></td>
</tr>
<tr>
<td>vs H1: lambda&lt;&gt;0</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td></td>
</tr>
<tr>
<td>H0: lambda=1</td>
<td>LL0=341,047</td>
<td>LL0=484,515</td>
<td>LL0=161,642</td>
<td>LL0=284,857</td>
<td>LL0=69,242</td>
<td>LL0=167,475</td>
<td></td>
</tr>
<tr>
<td>vs H1: lambda&lt;&gt;1</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 accepted</td>
<td>H0 rejected</td>
<td>H0 accepted</td>
<td>H0 rejected</td>
<td></td>
</tr>
</tbody>
</table>

(*) The successive results are: - for the dynamics, the parameter and its significance (*<1",""**" if >1 and <2; "***" if >2)
- for the exogeneous variables: the significance, the lambda value (italic) and the elasticity value (annual mean for 1975-84-92)

significance: * if the student-ratio<1, ** if it is <2 and >1, *** if it is >2
Table 4: Final model’s parameters, for the period 1975-1999

<table>
<thead>
<tr>
<th>TRAFFIC</th>
<th>ACCIDENTS</th>
<th>DEATHS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>motorw.</td>
<td>toll</td>
</tr>
<tr>
<td>Traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>motorways</td>
<td>0.78669</td>
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<td>toll motorways</td>
<td>0.91972</td>
<td>1.68779</td>
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<td>main roads</td>
<td>0.46594</td>
<td>0.48381</td>
</tr>
<tr>
<td>Economy</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>network length</td>
<td>0.39067</td>
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<td>household consumption</td>
<td>0.13239</td>
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</tr>
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<td>fuel price</td>
<td>-0.11401</td>
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<td>Average meteorology (diff)</td>
<td></td>
<td></td>
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<tr>
<td></td>
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</tr>
<tr>
<td>Summer temperature</td>
<td>0.00017</td>
<td>0.00024</td>
</tr>
<tr>
<td>Winter temperature</td>
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</tr>
<tr>
<td>Rain</td>
<td>-0.00001</td>
<td>-0.00001</td>
</tr>
<tr>
<td>Frost</td>
<td>0.00047</td>
<td>0.00104</td>
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<td>Atypical meteorology</td>
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<td></td>
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<tr>
<td>Summer temperature (I)</td>
<td>0.00080</td>
<td>-0.00162</td>
</tr>
<tr>
<td>Winter temperature (I)</td>
<td>-0.00348</td>
<td>-0.00032</td>
</tr>
<tr>
<td>Winter temperature (S)</td>
<td>0.00189</td>
<td>0.00224</td>
</tr>
<tr>
<td>Rain (S)</td>
<td>0.00040</td>
<td>-0.00046</td>
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<tr>
<td>Frost (S)</td>
<td>-0.00217</td>
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<tr>
<td>Calendar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>-0.00109</td>
<td>0.00312</td>
</tr>
<tr>
<td>S2</td>
<td>0.00295</td>
<td>0.00541</td>
</tr>
<tr>
<td>S3</td>
<td>0.00936</td>
<td>0.01591</td>
</tr>
<tr>
<td>MAPRE_R</td>
<td>2.16%</td>
<td>2.85%</td>
</tr>
<tr>
<td>R²</td>
<td>56.00%</td>
<td>58.00%</td>
</tr>
<tr>
<td>AIC</td>
<td>-1187.94</td>
<td>-1023.62</td>
</tr>
</tbody>
</table>

Nota: significance * if t-ratio is less than 1, ** if t-ratio is between 1 and 2, *** if t-ratio is greater than 2.
Atypical meteorology: read I for inferior atypicity and S for superior atypicity
Calendar variables: S1, S2, S3 have been constituted in order to have homogenous classes.
Session 16  Traffic Calming and Speed Management

The impact of seatbelt wearing on driver speeds in urban areas
C.J. Mollett

Setting of speed limits in south Africa
Dick Slater

Traffic calming measures. The experience of their implementation in urban areas in Greece
M. Pitsiava

Traffic calming and management strategy for a local distributor facility
Andre Frieslaar
Paper 3

The impact of seatbelt wearing on driver speeds in urban areas

By CJ Mollett and Dr CJ Bester

The objective of this paper is to test the hypothesis that the improved safety a driver achieves from wearing a seatbelt will cause him/her to compensate for the reduction in risk by driving faster – as according the risk homeostasis phenomenon. The paper will also try to identify certain driver and vehicle characteristics that could influence the driver speeds. The non-wearing of seatbelts is certainly a problem on all three continents – the question however must be asked what effect on travel behaviour will an increase in the seatbelt wearing rate have – could it cause drivers to drive faster because wearing seatbelts will make them feel safer?
SETTING OF SPEED LIMITS IN SOUTH AFRICA

Dick Slater (National Department of Transport)
Christo van As, Herman Joubert (Gibb Africa)

ABSTRACT

General speed limits in South Africa are prescribed in the National Road Traffic Act and Regulations. These limits, however, do not accommodate all possible conditions that may occur on roads – therefore the need for a procedure for the setting of speed limits. The National Department of Transport has undertaken a study on speed limits and developed a new procedure for the setting of speed limits. Proposals have also been made regarding a new approach to managing speed limits.
SETTING OF SPEED LIMITS IN SOUTH AFRICA

Dick Slater, Christo van As, Herman Joubert

1. INTRODUCTION

South Africa has a bleak history of road accidents. During the past decade, accidents have annually claimed the live of approximately 10 000 people, of which more than 4 000 were pedestrians. Accidents are currently leaving approximately 40 000 people seriously injured in one year. Many of these will suffer the consequences of the accidents for life. Although various factors contribute to these accidents, including alcohol and negligence, excessive speed seems to be one of the major causes for accidents.

General speed limits in South Africa are prescribed in the National Road Traffic Act and the National Road Traffic Regulations. General speed limits, however, cannot accommodate all possible conditions that may occur on roads, and provision has therefore been made for the posting of lower or higher speed zone limits on particular roads and streets.

The Traffic Act and Regulations do not prescribe a method or procedure for the setting of speed zone limits. The CSIR Technical Report RV/19 "Guidelines for setting speed limits" was developed for this purpose. Although it was applied in some provinces, it did not gain widespread support. The South African National Department of Transport has established that an urgent need exists for a revision of this document for the setting of speed limits. This was in response to the increased debate on speed limits in the country, as well as the high levels of speeding which are being experienced on South African roads.

The Department has undertaken a study on speed limits and the purpose of this paper is to present the main findings of this study. The research report RR 96/006 Setting of Speed Limits in South Africa (June 1998) can be obtained from the Department.

The main objective of the study was to revise the current guidelines for setting speed limits for all classes of roads and streets. A further objective of the study was to consider the possible lowering or raising of speed limits of the general 60 km/h and 100 km/h speed limits (an investigation into the maximum speed limit of 120 km/h was specifically excluded from the study). The feasibility of introducing differential speed limits for different vehicle classes, wet and dry conditions as well as day and night conditions was also investigated.

2. STUDY METHODOLOGY

The methodology followed during the study consisted of the following:

a) **Evaluation of existing local and overseas practices and other information.** A major review of research and other reports was undertaken during the course of the study. Information was obtained from various countries in the world. More than 200 reports were collected and reviewed during the study.

b) **Evaluation of South African data on accidents and speeds.** South African data on accidents and speeds were obtained from a number of organisations. Additional speed observations were undertaken during the study.

c) **Questionnaires and consultation with interested parties.** An important phase of the study was to obtain and assess views of road and traffic authorities, organisations and other interested parties on issues regarding speed limits. These views were collected by means of questionnaires and interviews.

d) **A study tour of roads in South Africa.** A study tour was undertaken to various regions in South Africa to investigate road and traffic conditions. An attempt was made to inspect as many road types and environments as possible during the tour. Current speed limits
were noted together with a number of road and environmental characteristics. It was thus possible to establish a relationship between the typical speed limits found on South African Roads and various road characteristics.

e) Evaluation of proposals by the STOP committee of traffic experts. The STOP (Safety in Traffic Operations Programme) committee was responsible for providing guidance and monitoring the project and approving recommendations made in the report.

3. SPEED LIMITS IN PRACTICE

Information on speed limit practices was obtained from a number of countries, including the United States of America, Canada, the United Kingdom, European countries and Australia. South African speed limits compares as follows with limits in these countries:

a) The urban speed limit used in most countries is 50 km/h, but it varies between 40 km/h and 60 km/h. The 40 km/h limit is used in some states of the United States, while the 50 km/h limit is popular in Canada and a number of European countries. The South African limit of 60 km/h is somewhat high, but it is not the only country with this limit.

b) The speed limit on overseas rural roads varies between 80 and 112 km/h. The South African general limit of 100 km/h falls within this range.

c) The freeway speed limit in most countries varies between 100 and 120 km/h, but a number of countries in Europe apply higher speed limits. The South African speed limit of 120 km/h is high compared to limits in Australia and the United States, but average compared to the European countries.

d) Heavy vehicle speed limits typically vary between 90 and 100 km/h, with a few countries applying a limit of 80 km/h. Many countries have no differential speed limits for heavy vehicles. The South African limit of 80 km/h for heavy vehicles appears to be somewhat low in comparison.

e) Countries have not all introduced speed limits for buses. Those countries that have such limits typically apply a speed limit of 100 km/h.

f) Speed zone limits in many countries are primarily established based on 85th percentile speed, although limits are adjusted for factors such as roadside development and road geometry.

4. SPEED LIMITS AND SPEEDING

It is axiomatic that speed limits affect safety only if limits affect the actual speed selection of drivers. There is little point in establishing a speed limit, however desirable, if it is not going to have any effect on actual vehicle speed. This issue was investigated in some detail during the study.

Speed observations undertaken during the study indicated that there is a considerable extent of speeding in South Africa. Speeding was found to be especially prevalent on roads with lower speed limits. In some cases, it appears as though drivers were of the opinion that the speed limit is the minimum limit since nearly all drivers were found to travel faster than the limit. The 120 km/h speed limit, however, was not exceeded to the same degree as the 100 km/h and lower limits. The 80 km/h speed limit for heavy vehicles was also exceeded by a large number of heavy vehicles.

The higher non-compliance rate on 100 km/h roads seems to indicate that many South African drivers are under the impression that a 120 km/h limit applies to rural roads, and not the 100 km/h limit. The reason for the higher compliance rate on the 120 km/h roads, however, could also simply be that many vehicles do not have sufficient power to reach the high speeds or that drivers do not consider higher speeds to be safe for prevailing conditions on such roads.

South Africa is not the only country in the world which is experiencing problems with the non-compliance of speed limits. A review of a number of overseas reports indicated that the problem
is rather widespread throughout the world, and that the problem has been experienced for a number of decades. Various studies in other countries indicated that large numbers of drivers exceed speed limits, and that speed limits have little influence on vehicle speeds.

The current situation concerning speeding in South Africa is unsatisfactory. Many persons appear to support the use of speed limits, and even very low speed limits, but simply continue to ignore speed limits as if they do not exist and treat them with contempt. These problems have now been experienced for a number of decades, which suggest that either no will or desire exists to enforce speed limits, or that traditional forms of law enforcement have failed in curbing speeding.

An urgent need exists for new and innovative approaches to control and manage speeds. The most promising approach appears to be the application of engineering solutions where physical impediments are placed in the way of drivers (speed calming measures). Safety problems will not be addressed by simply continuing posting speed limits that are ignored by most drivers. It is, however, not surprising that speed limits are being ignored when speed limits are posted which are considerably lower than the design speed of a road.

5. SPEED LIMITS AND SAFETY

Speed control and management has been identified as one of the most important measures to reduce speed-related accidents. The severity of accidents increases exponentially with higher speed. It also becomes more difficult to avoid accidents at high speed because of reaction time and the greater difficulty of controlling vehicles at such speeds.

It does however not follow that changing a speed limit will automatically increase or reduce accidents. It is not necessarily speed that kills, but speed that is inappropriate for prevailing conditions. Low speed is as likely to kill as high speed, for example a truck that travels at a very low speed at night on a high-speed road. There is also a tendency in South Africa to assume that it is safe to travel at the speed limit under all circumstances.

South African data on the relationship between accident rates and speeds indicated a great amount of dispersion, and it was not possible to obtain a significant relationship between accident rate and speed. This does not imply that such relationship do not exist – it simply means that the quality and quantity of the available data was inadequate. South African data on the main causes contributing to fatal accidents do, however, indicate that excessive speeding may be one of the most important reasons for deaths on our roads. This data, however, is based on subjective evaluations and are therefore not necessary factual.

A review of international literature indicates that there is some difficulty in proving a relationship between accidents and speed. There are many contrary findings that warrant some caution when using research results. One of the main problems appears to be isolating speed as a single contributing factor in accidents.

The basic problems with establishing a speed limit are that it applies to a wide range of conditions and that it represents a compromise between mobility and safety. There is considerable controversy on this issue, which makes the establishment of numerical speed limits extremely difficult and contentious. The only safe speed is zero, since accidents occur at all speeds (it could even be argued that a zero speed is not necessarily safe). A speed limit is therefore a trade-off that must be accepted by both those who are in favour of lower limits, as well as those in favour of higher limits. It should, however, also be acknowledged that a speed limit is perhaps not the best method of speed control and that alternative measures could be more effective.
6. THE NEED FOR SPEED LIMITS

The need for speed limits is clearly recognised throughout most countries of the world - with few countries allowing unlimited speeds. The problem, however, with a speed limit is that it is not the ideal method of controlling speed. In fact, it has a number of very important disadvantages.

One of the most important limitations of speed limits is that limits are normally established for favourable conditions. Drivers are then expected to reduce speeds according to their judgement when prevailing conditions are poor. It is ironic that drivers are allowed to use their judgement when conditions are unsafe, and not when it is safe.

A notion also exists that a speed limit can be precisely established using scientific methods, and that it should be treated as an absolute value. This is highly improbable; in fact no single speed can be considered as a precise limit of safety.

A further problem with speed limits is that there is little sense in having such limits if they are not consistently enforced. If a speed limit is not enforced, then drivers transgressing the law are perceived by others to have an unfair perceived advantage (commercial vehicles could even have an unfair economic advantage due to faster turn-around times). Allowing some persons to exceed the speed limits also has a number of serious safety repercussions. Drivers have to observe the speed limit, not only for their own safety, but also the safety of other users of the road, including vulnerable road users such as pedestrians, cyclists, the young and the elderly. The recommendations of the report were therefore made subject to the strict enforcement of speed limits.

The main advantage of a speed limit is that it serves as a general control on drivers, indicating to drivers that they are subjected to limits. It is especially important to restrict drivers from travelling at too high speeds. The designs of road signs and traffic signals are also dependent on the speed limit. The length of no-overtaking lines, for example, is directly dependent on the speed limit. Traffic signal settings and particularly the critically important amber periods are also set according to the speed limit.

7. SPEED LIMIT PRINCIPLES

A procedure for establishing speed limits must ensure that the limits are both realistic and objective in order to achieve the potential benefits of consistent and uniform speed regulations. It is of utmost importance that speed limits should be perceived as reasonable by the majority of drivers. Unrealistic speed limits that fail to gain the respect of drivers will be largely ignored and will undermine respect for speed limits in general.

Many speed limits in South Africa appear to have been established arbitrarily, especially in urban areas. This is probably one of the main causes for the inconsistent speed limits found in the country. The arbitrary approach, however, has been applied due to shortcomings in existing procedures for setting speed limits.

The engineering approach to the establishment of speed limits attempts to establish the maximum safe speed on a road on the basis of fundamental engineering principles. Most of the models are mathematical in nature, but based on empirical observations of basic parameters. The engineering approach, however, does not cater for all conditions, and must therefore be supplemented by measurements of the 85th percentile speed.

The 85th percentile speed is used as a norm in setting speed limits in many countries. It has been argued that the 85th percentile speed serves as a norm set by drivers themselves, and that it should therefore find a high degree of acceptance. The normally cautious and competent actions of a reasonable person should be considered legally acceptable. Drivers, however, do not always fully consider all conditions, and reliance can therefore not always be placed on their judgement of safe speeds.
8. GENERAL SPEED LIMITS

The following general speed limits were proposed during the study:

a) *Urban speed limit.* The current general urban speed limit in South Africa is 60 km/h, while a lower speed limit of 50 km/h is used in many other countries. The problem in many South African cities is that the functional hierarchy of the road network is often poor or even non-existent. Narrow residential streets are sometimes used as major arterials. It is therefore highly unlikely that lower speed limits in South Africa will result in lower speeds. The solution to the problem is to provide an environment in which it is difficult, if not impossible, to speed. It was therefore proposed that the general speed limit of 60 km/h be retained, but that road authorities should be encouraged to use proper design guidelines when new residential areas are developed and to use traffic calming techniques in all sensitive residential areas.

b) *Rural speed limit.* The current rural road speed limit in South Africa is 100 km/h, which applies to roads other than freeways. A speed limit of 120 km/h has however been posted on a large number of these roads as allowed by the National Road Traffic Regulations. It also appears that many South African drivers are unaware of the general 100 km/h limit. *Speed limit signs, however, have not been posted on all rural roads.*

Many of these roads are also of a relatively high design standard, which creates the impression that a speed limit of 120 km/h could apply. It would therefore be unfair to prosecute drivers who exceed the 100 km/h speed limit on such roads. This is also of specific relevance to the high number of foreign visitors and tourists in South Africa.

In order to address this problem, it is preferable that speed limits should be posted on all paved rural roads in South Africa, even if the general limit applies. This could in fact eliminate the need for a general rural speed limit. It was, however, proposed that the 100 km/h be retained as a "default" limit in the absence of a posted speed limit. This limit should also be retained for all rural gravel roads.

c) *Maximum speed limit.* The investigation of the 120 km/h general maximum limit was specifically excluded from this study. It is, however, important to reiterate that the problem of speeding should be urgently addressed. It cannot be allowed that a large number of drivers should continue to ignore the general speed limit. If this situation should be allowed to continue, then the consequence is not only an increased risk of accidents, but also that drivers will lose their respect for traffic laws and regulations.

d) *Speed limits for different vehicle types.* A general speed limit of 80 km/h is currently in force for heavy vehicles in South Africa. This speed limit, however, is unrealistic and could result in various problems if properly enforced. Compliance with the limit would also increase impedance of other traffic due to increased catching up rates. The South African Road Freight Association, however, is not in favour of increasing the limit because of the poor quality of many heavy vehicles. It was therefore proposed that the 80 km/h speed limit should be retained (and with strict law enforcement).

The consequences of accidents involving *mini-buses, buses* and *coaches* are significantly greater than those of heavy vehicles. Statistics show that between six and eight persons are killed or seriously injured per ten mini-buses and buses involved in accidents, while only one person is killed or seriously injured per ten heavy vehicles involved in accidents. It was therefore proposed that a speed limit of 100 km/h be introduced for mini-buses, buses and coaches. This proposal has recently been implemented in South Africa.

The National Road Traffic Act provides for the voluntary display of speed limits on the rear ends of vehicles subject to differential limits. It was proposed that this display must be made mandatory.

e) *Enforcement tolerances.* Tolerances vary between jurisdictions throughout South Africa. This creates an unfair and confusing situation in South Africa that can no longer
be condoned. It was therefore recommended that a tolerance should be recommended as “good practice”. A tolerance of 10% (subject to a minimum of 5 km/h) was proposed for this purpose.

9. **SPEED LIMITS FOR SPECIAL CONDITIONS**

A number of speed limits for special conditions that warrant differential speed limits were considered during the study. These are the following:

a) **Variable speed limits.** These are used under circumstances where speed limits are changed according to prevailing weather and operational conditions. Variable advisory speeds are preferred to variable limits (because of the likelihood that offending drivers can claim confusion during prosecution because of changing speed limits).

b) **Speed limits for wet conditions.** Driving in wet conditions can be particularly dangerous, not only because of reduced skid resistance, but also due to reduced visibility and more importantly, the possibility of hydroplaning. Although desirable, there are a number of problems with the implementation of general speed limits for wet conditions, of which the most important is the difficulty in finding a legal definition for wet conditions. Such speed limits were therefore not recommended.

c) **Speed limits for night conditions.** Driving at night in South Africa is particularly dangerous and night speed limits can therefore be justified. Night speed limits should be posted on roads that experience a high accident rate at night (but only if the limits are likely to be effective).

d) **Speed limits at schools.** Lower speed limits at schools are justified because children are less experienced road users and high speed poses a particular danger near schools. Studies, however, have indicated that such speed limits are ineffective in controlling speeds. It is therefore proposed that such speed limits should not be used, but that physical measures should be introduced to control speeds at schools.

e) **Minimum speed limits.** Minimum speed limits on roads, and particularly freeways, are justified on the basis that they reduce the speed differential, and therefore the accident potential. Minimum limits also have the advantage that travel impedance on roads would be reduced. The problem with minimum limits, however, is that no practical alternative choices are provided to a driver who is trapped in a situation where he or she is unable to comply with the minimum limit. For this reason, minimum speed limits should only be introduced on the faster inner lanes of multiline roads. Minimum speed limits should also be established according to specific conditions on a road and it is not possible to prescribe a general minimum speed limit.

10. **SPEED ZONING**

Speed zoning is the process of establishing safe and reasonable speed limits for specific sections of roads and streets. Such limits are established based on factors that are considered to contribute to road accidents. Two broad approaches can be followed in the identification of such factors, namely the less detailed and the more detailed approaches. The more detailed approach is more objective and would have been ideal, but insufficient information is currently available) to establish speed limits on this basis. The cost of establishing and implementing such a procedure would also be very high. The less detailed approach was therefore recommended in which speed limits are prescribed in general terms, and reliance placed on “engineering judgement”. This process is supplemented by 85th percentile speed observations.

A problem with speed limits is that conditions tend to change over the length of a road. Speed limits should therefore ideally be continuously adjusted to suit such conditions. This, however, is unpractical and would be highly confusing to drivers. It was therefore recommended that greater use of advisory speeds should be made in South Africa to warn drivers of isolated problems on a road.

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Speed limits should preferably be used in situations where accidents arise from conflicts between different road users, while advisory speeds should be used in situations where accidents primarily arise due to interaction between a driver and the road environment (accidents do not involved other road users). This approach implies that advisory speeds would be used in situations normally associated with the geometry of a road as well as roadside hazards (such as narrow bridges). Speed limits would be used in situations normally associated with roadside development, and would occur because of vehicular access, pedestrian movements, parking, etc.

The most important factors in establishing speed limits were found to be land-use, road type (access control) and type of intersection control. A further factor is sight distance, but only when it is judged that speeds would not be better controlled by means of advisory speed signs.

The proposed limits were established based on current limits in South Africa, as well as limits used in other countries. The limits are mainly those that were typically found on many South African roads during the study tour.

The proposed procedure is described in detail in the original research report. The procedure is relatively simple to apply, requiring the minimum of data observations. The intention is to include the procedure as a chapter of the South African Road Traffic Signs Manual.

The procedure has been circulated to various road authorities for comments. This has resulted in a number of small changes to the procedure. Most of the changes were aimed at clarifying the procedure. The latest available version is one dated 01/01/1999.

The procedure has also been applied in a pilot project in Centurion. The procedure was found to produce realistic speed limits in urban areas. The speed limits are slightly higher than existing speed limits, but lower than observed 85th percentile speeds.

11. **NEW SPEED ZONING PROCEDURE**

The proposed new procedure for setting speed limits consist of the following steps:

1. **Homogeneous sections.** The road is first subdivided into homogeneous sections on which only one speed limit is applied. Such sections are selected in such a way that drivers would clearly be able to recognise the need for different speed limits. Absolute and desirable minimum lengths of speed zones are prescribed in the procedure.

2. **Vehicle test runs.** Vehicle test runs are undertaken with the purpose of establishing a speed profile for a road. These test runs should preferably be undertaken with a vehicle fitted with electronic equipment that can record and measure distances and speeds. The speed should be as close as possible to the actual 85th percentile speed over the length of the road. The speed profile is used to determine whether the 85th percentile speed measurements would be important in the establishment of the speed limit, and if so, to establish the location where such speed measurements should be made.

3. **Speed limits.** The speed limit applicable to the homogeneous road section is the lowest value established based on the following factors:

   a. **Road class.** The class of road (e.g. arterial, local, etc.) is taken into account when setting speed limits. Higher speed limits can be used on the higher classes of roads.

   b. **Land-use and access.** Land-use adjacent to the road is an important factor in the establishment of speed zone limits, but only if direct access is given to vehicles or when pedestrians can gain indirect access to the road. A special class for which provision is made is rural settlements.

   c. **Intersections.** Intersections are particularly dangerous points, and lower speed limits in the immediate vicinity of intersections are required. Provision has been made for different types of intersection control (e.g. traffic signals, priority control, etc.)
d. **Parking and loading.** Parking or loading should not be allowed on the pavement of a road with a speed limit higher than 60km/h. If no alternative parking or loading facilities are available, a speed limit of 60 km/h should be introduced.

e. **Accident experience.** Speed limits may be lowered based on a detailed and well-motivated road safety audit of a road. The type of accidents must, however, be clearly related to high speeds. Furthermore, appropriate measures must be instituted to ensure that the speed limit will be effective. A speed limit should then be introduced on a temporary basis to establish whether it had any real beneficial effects on the accident rate.

f. **Sight distances.** Sight distance is a principal consideration in road safety. The speed limit may be reduced when sight distance is inadequate. However, such reduction should only be introduced when it is judged that the problem would not be adequately addressed by means of an advisory speed sign.

g. **85th Percentile speed.** The 85th percentile speed is used to serve as an upper limit for the speed limit. It can not be used to justify a speed limit higher than those established by one of the other factors. In such a case, however, it is unlikely that a lower speed limit would be effective, and all reasonable effort should be made to alter the environment or road geometry (e.g. traffic calming measures) as to achieve an 85th percentile speed which is close to the speed limit.

11. **ADVISORY SPEEDS**

Advisory speed signs are used to indicate safe speeds for specific isolated problems on a road and which arise due to geometric problems or roadside hazards (such as narrow bridges). **Advisory speeds are particularly useful in that they can reduce the need to vary speed limits along a road.** However, when problems occur continuously along the length of a road, it becomes unpractical to use advisory speeds repeatedly, and a speed limit should then be posted.

A procedure for the establishment of advisory speeds was developed during the study and will be included in the chapter on setting speed limits. The proposed method differs slightly from standard engineering practices because of criticisms that were raised against current methods. The proposed method is described in detail in the original report.

12. **SPEED LIMITS AT ROAD WORKS**

Speed limits at road works are required not only to safeguard construction workers, but also the motorist because of the higher danger resulting from the increased level of activity at road works. Work zones are also particularly dangerous on high-speed roads because of the speed adaptation problem.

A major problem in South Africa is that few drivers adhere to speed limits at road works. A possible reason for this is that roadwork limits have not been properly managed and controlled by road authorities and contractors. In order to prevent the abuse of speed limits at work zones, it is proposed that all such limits be **certified** by a qualified professional. Any uncertified speed limit at road works should become a punishable offence under the National Road Traffic Act.

Speed limits at road works are recommended based on a number of factors. The most important of these is the proximity of the work to the travelled way. Road works should also be planned to minimise the impact on road users, particularly on high-speed roads where drivers cannot be expected to reduce their speed to unrealistically low limits.

RJV SLATER
13. SPEED MANAGEMENT SYSTEM

The establishment of speed limits is a complicated engineering exercise, which in the past in South Africa has not received the attention it requires. Speed limits have therefore been posted which are inconsistent, leading to the perception amongst drivers that they are unfair, and that the sole purpose of the limits is to prosecute drivers to generate income and not to improve safety.

It has become necessary, therefore, that steps should be taken to ensure that appropriate speed limits are established on all South African roads in both rural and urban environments. Such speed limits should only be established according to the proposed guidelines, by a person adequately qualified to perform the required tasks.

*It was therefore proposed that all speed limits should be established by adequately qualified practitioners. Moreover, it is also recommended that a certificate be issued by such a person for each speed limit introduced (including at road works). Speed prosecution will then only be allowed when a certificate has been issued and lodged with the provincial government.*

*It was also proposed that provincial governments should also institute Speed Limit Review Boards, which will have the main task of overseeing the process of establishing speed limits. The National Road Agency should also establish such a Board for all national roads.*

14. CONCLUSIONS AND RECOMMENDATIONS

The study concluded that speeding is prevalent on South African and that the situation is unsatisfactory. Many persons appear to support and propagate the use of low speed limits, but speed limits continue to be ignored and treated with contempt. The study did, however, indicate that it is difficult to establish a speed limit that is applicable to the wide range of conditions that can occur on roads, and that any speed limit is a compromise between mobility and safety. There is, and will continue to be, considerable controversy on this issue. The establishment of speed limits remains a difficult and questionable issue.

The recommendations of the study were accepted and approved by COLTO (Committee of Land Transport Officials). Some of the proposals require changes to the National Road Traffic Act and the National Road Traffic Regulations, which would require approval by the South African Parliament.

15. ACKNOWLEDGEMENTS

The Department of Transport is gratefully acknowledged for permission to present this paper. The views and opinions expressed in this paper are those of the authors and do not necessarily represent Department of Transport policy.

The STOP (Safety in Traffic Operations Programme) committee was responsible for monitoring the project and approving recommendations. The members of the committee were the following:

- GJ Botha (Department of Transport)
- RJV Slater (Department of Transport)
- G Botha (Free State Provincial Government)
- WJ Gorny (KwaZulu-Natal Department of Transport)
- MR Meijer (Gauteng Department of Transport and Public Works)
- CJ Mollett (Western Cape Department of Transport and Public Works)
- B van Rooyen (Kodok)
- W van Zyl (Gauteng Traffic Services)
- D Bain (DLC)

RJV SLATER
EJ Roberson (Ninham Shand)
G Schermers (CSIR)
E Cornelius (COASA)
C Pierides (Road Freight Association)

16. REFERENCES

Title: Traffic calming in Pretoria - effectiveness of mini circles and design of speed humps

Authors: Mr Helius Visser, Senior Engineer, Division Transportation and Traffic Flow, City Council of Pretoria
         Mr Jan Coetzee Pr Eng, Managing Director, Innovative Traffic Solutions (Pty) Ltd

ABSTRACT

The Pretoria City Council was one of the first Councils in South Africa to implement traffic calming. Several experiments have been carried out with different designs for mini circles, speed humps and other traffic calming devices. As traffic calming is a reactive measure, it is constantly necessary to monitor the effectiveness of the measures and to improve the design thereof.

The City Council of Pretoria is at present carrying out research on three traffic calming aspects, namely:

- An evaluation of the effectiveness of mini circles and the preparation of a new mini circle design.
- Development of a construction method for speed humps and determining the best materials to use.
- The compilation of a prioritisation process (warrants) for the implementation of speed humps and raised pedestrian crossings.

The evaluation of mini circles consist of determining the effectiveness in reducing speed, the ease of use thereof for motorists, mini circles as a traffic control measure, etc. Measurements are carried out at circles with inductive loops and radar at different distances from the mini circle to measure speed. This will be used to determine characteristics such as are speed humps always necessary at mini circles, what should be the ideal height of the circle island. Motorists

To date speed humps in Pretoria have been constructed with asphalt and methods used did not always result in speed humps of constant shape and effectiveness. Global research show that the preferred profile is a circle segment with a height of 75 mm to 100 mm and a length of approximately 3.7 m. Testing of shapes and construction methods is done to determine the most applicable method for Pretoria's local conditions.

The warrants for traffic calming developed by the CSIR provide a good basis for deciding when to implement traffic calming and specifically speed humps and raised pedestrian crossings. The use of these warrants has however proved to be not that easy in practice and additional research is necessary to find a set of parameters that typically apply to Pretoria's local conditions.

The proposed paper will describe the above aspects, will provide valuable feedback and experience to practitioners in the field and will make a contribution to the national traffic calming knowledge pool.
TRAFFIC CALMING & MANAGEMENT STRATEGY
FOR A
LOCAL DISTRIBUTOR (CLASS 4) FACILITY

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Introduction
Traditionally traffic calming has been applied to residential (Class 5) roads to deal the need to eliminate extraneous traffic from a residential area and/or to reduce speeds of vehicles using residential streets, both for obvious safety reasons. The traffic calming strategies involve the use of regulatory measures like stop signs, speed limit signs etc., and/or geometric features like speed humps, traffic circles, etc. A comprehensive list of traffic calming devices/strategies is indicated in Table 1. These traffic calming devices are needed to treat the symptoms of a poorly performing higher order road network, rather than deal with the cause. Often by improving the performance of the higher order road network, traffic should return to these higher order routes, due to the reduced travel time and increased convenience, thereby removing the traffic from the residential streets and eliminating the need for traffic calming.

Table 1: Traffic Calming Devices/Strategies Applicable to Class 5 Roads (Residential Streets) (Ref 1)

<table>
<thead>
<tr>
<th>Regulatory Measures</th>
<th>Geometric Features</th>
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<tbody>
<tr>
<td>Stop signs (2 or 4 way)</td>
<td>Pavement undulations (Speed humps)</td>
</tr>
<tr>
<td>Yield Signs</td>
<td>Traffic circles</td>
</tr>
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<td>Traffic Signals</td>
<td>Median barriers</td>
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<td>Speed limit signs &amp; speed zoning</td>
<td>Semi diverters (half closures)</td>
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<tr>
<td>Turn Prohibitions</td>
<td>Forced turn channelisation</td>
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<tr>
<td>One way Street Design</td>
<td>Chokers</td>
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<tr>
<td>Access regulation</td>
<td>Diagonal Divertors</td>
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<tr>
<td>Truck Restrictions</td>
<td>Cul de sac at intersections</td>
</tr>
<tr>
<td>Parking Controls</td>
<td>Midblock cul de sacs</td>
</tr>
<tr>
<td>Guide &amp; warning controls eg. School zone signs, slow signs, road markings, crosswalk pavement markings, lane reduction &amp; novelty signs</td>
<td>Raised intersections</td>
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<td></td>
<td>Rumble strips</td>
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<td></td>
<td>Transversable barriers</td>
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<td>Road curvature &amp; pavement irregularities</td>
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</table>

Traffic Calming on Local Distributors (Class 4 Routes)

Local distributor (Class 4) routes can be defined as through routes that distribute traffic within communities and link district distributors (Class 3) routes and residential streets (Ref 2). These routes may accommodate the local bus/taxi routes, but should not carry extraneous traffic. Often non residential land uses such as community facilities and commercial uses are found along these routes. Local distributors therefore have both an access and a mobility function. The mobility function of these routes has to be preserved or else traffic will divert to the residential
streets, thereby resulting in a traffic calming problem. Requests for traffic calming on Class 4 roads lead to a tradeoff between mobility and safety. Therefore, traffic calming measures that can retain the route mobility and increase the safety of all users are applicable for use on Class 4 routes. A summary of the relevant traffic calming devices/strategies for Class 4 routes is indicated in Table 2.

**Table 2: Traffic Calming Devices/Strategies Applicable to Class 4 Roads (Local Distributors)**

<table>
<thead>
<tr>
<th>Regulatory Measures</th>
<th>Geometric Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop signs (2 or 4 way)</td>
<td>Traffic circles</td>
</tr>
<tr>
<td>Yield Signs</td>
<td>Median barriers</td>
</tr>
<tr>
<td>Traffic Signals</td>
<td>Forced turn channelisation</td>
</tr>
<tr>
<td>Speed limit signs &amp; speed zoning</td>
<td>Raised intersections</td>
</tr>
<tr>
<td>Turn Prohibitions</td>
<td>Rumble strips</td>
</tr>
<tr>
<td>One way Street Design</td>
<td>Transversable barriers</td>
</tr>
<tr>
<td>Access regulation</td>
<td>Road curvature &amp; pavement irregularities</td>
</tr>
<tr>
<td>Truck Restrictions</td>
<td></td>
</tr>
<tr>
<td>Parking Controls</td>
<td></td>
</tr>
<tr>
<td>Guide &amp; warning controls eg. School zone signs, slow signs, road markings, crosswalk pavement markings, lane reduction &amp; novelty signs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The major differences between Tables 1 & 2 are the reduced number of geometric features applicable to Class 4 routes. Speed humps, semi diverters, chokers, diagonal divertors or any form of cul de sac would significantly impact on the capacity and mobility of the Class 4 route, and are hence inappropriate for Class 4 routes.

**Case Study**

Ottery Road in Wynberg (a suburb of Cape Town) is classified as a Class 4 route and extends from Prince George Drive (Class 3) in the south east, to the CBD of Wynberg in the north west (Refer to Figure 1). The Wynberg public transport interchange is located at the northwestern end of Ottery Road and hence Ottery Road carries high public transport flows. Three schools are located along Ottery Road, as well as three churches. A small commercial node has developed at one location along the route, while the remainder of the route is predominantly residential. The route is approximately 1.2 km long and vehicles could travel uninterrupted by traffic control devices along the entire length of the route. The closest parallel (alternative) route to Ottery Road is Prince George Drive (Class 3) and Broad Road (Class 4). The length of the alternative route is approximately 1.45 km.

A firm of Traffic Engineers and Transport Planners was appointed to conduct this study, and an Urban Designer was subcontracted onto the professional team to provide an integrated approach to traffic calming. A project management team, comprising representatives from the Local Ratepayers Associations and officials from the Local Authority, met with the professional team at key milestones in the project to discuss proposals.

Numerous requests for traffic calming on Ottery Road had been received from local residents, hence prompting the study. Of particular concern was the speeding of vehicles along the route during off peak hours, and the safety of school children crossing the route during peak periods.
To a lesser extent, reckless driving, the risk of accidents and traffic volume were also of concern to the local community.

Other problems along Ottery Road, that were identified during the study were as follows:

- Sections of the route were very wide (in excess of 4 metre lanes in each direction) and the route was very straight, i.e. long views along the route in both directions.
- The lack of definition of the road edge i.e. no defined kerb edge over certain sections.
- The existence of potentially dangerous tree stumps in close proximity to the travelled way.
- Wide, underutilised and undefined parking areas resulting in irregular vehicle manoeuvres.
- Lack of embayed parking.
- Lack of bus stops near schools.
- The general loss of quality in derelict roadside environments.

**Existing Traffic Situation**

Traffic data for the existing situation (1996) was collected in the form of intersection turning movement counts and travel time surveys. These surveys were conducted during the weekday morning and afternoon commuter peak periods and during an off peak period i.e a period during which the route operated under free flow conditions. Accident data for the route was obtained from the Local Authority.

The traffic flow data for the route is summarised in Table 3. Peak hour two way link flows on Ottery Road were found to be high (1 100 to 1 450 vehicles per hour during the AM peak hour and 950 to 1 250 vehicles per hour during the PM peak hour). Based on a typically two lane road capacity of between 1 600 to 1 800 vehicles per hour (two way flow), the route was in general operating at under capacity conditions during peak hours. During the off peak, two way traffic flows were between 650 and 900 vehicles per hour.
Table 3: Traffic Flow Data for Ottery Road (1996)

<table>
<thead>
<tr>
<th>Section of the Route</th>
<th>Hourly Two Way Traffic Flow (Vehicles per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekday AM</td>
</tr>
<tr>
<td>Northern Section</td>
<td>1182</td>
</tr>
<tr>
<td>Southern Section</td>
<td>1439</td>
</tr>
<tr>
<td>Estimated AADT for the Entire Route</td>
<td>12,015</td>
</tr>
<tr>
<td>Estimated Yearly Flow for the Entire Route</td>
<td>4.1 million vehicles per year</td>
</tr>
</tbody>
</table>

Although the route operates at under capacity conditions and below its environmental capacity (1500 vehicles per hour two way flow) (Ref 2), the flows are high considering the number of pedestrians (mostly children) who use the route and need to cross the route during peak and off peak periods.

Public transport flows recorded on the route were high (two way flow of 490 taxis and 20 buses during the AM peak hour and 390 taxis and 23 buses during the PM peak hour).

A summary of the recorded average and 85th percentile speeds for various sections of the route are indicated in Table 4. Contrary to expectations, the average recorded speeds (space mean speed) for the various sections of the route, were below the posted speed of 60km/h, for both the peak hour surveys and the off peak hour survey. Isolated incidents of speeds in excess of the speed limit were recorded. The highest speeds were recorded along the northern sections of the route where the route is characterised by wide lane widths and a straight alignment. The highest pedestrian crossing activity occurs along this northern section.

Table 4: Average and 85th Percentile Vehicular Speeds on Sections of the Route

<table>
<thead>
<tr>
<th>Section</th>
<th>Direction</th>
<th>Space Mean Speeds (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weekday AM Peak Hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average Speed</td>
</tr>
<tr>
<td>Between Tyrone Road &amp; Essex Road</td>
<td>NB</td>
<td>35.87</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>49.70</td>
</tr>
<tr>
<td>Between Essex Road &amp; Park Road</td>
<td>NB</td>
<td>49.96</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>49.96</td>
</tr>
<tr>
<td>Between Bath Road &amp; Prince George Drive</td>
<td>NB</td>
<td>41.44</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>43.20</td>
</tr>
<tr>
<td>Entire Route: Byrnes Road to Prince George Drive</td>
<td>NB</td>
<td>42.31</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>45.38</td>
</tr>
</tbody>
</table>
Accident data that was obtained for the route is summarised in Table 5. On average, approximately 108 accidents occurred each year resulting in 20 injuries, two of which were serious injuries. No fatalities were recorded over this three-year period. Also indicated in Table 5 are the average accident rates per accident severity/type per 100 000 vehicles.

Table 5: Summary of Annual Accident Statistics for the Route (1993 to 1995)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Serious</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Slight</td>
<td>32</td>
<td>9</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>All Accidents</td>
<td>100</td>
<td>116</td>
<td>108</td>
<td>108</td>
</tr>
</tbody>
</table>

**Traffic Calming Strategy**

Based on the existing traffic situation assessment, the following strategies (Ref 1) were formulated to address the concerns of the local community:

- To change the street space i.e. altering the appearance of the street, thereby changing driver behaviour. This can be done by means of landscaping, kerbs, street surfaces and textured pedestrian/cyclist crossing points.
- To restrain long views, thereby forcing drivers to drive with more caution.
- To meander the kerb line, thereby forcing drivers to manoeuvre through a more complicated street space.
- To implement policies that introduce traffic management devices and street design changes compatible with the neighbourhood character and that are easy to maintain. Landscaping should be introduced to enhance the pedestrian environment.

The proposals put forward by the professional team and implemented by the local authority included the following:

- The narrowing of the roadway, particularly in the northern sections of the route. The kerb edges were brought in to create a kerb to kerb (travelled way) road width of approximately 7.4 metres. In certain areas, on street parking was embayed, thereby bringing the kerb line closer to the travelled way. In other areas, off street parking was provided in landscaped areas to the side of the narrowed road.
- The meandering of the roadway was achieved in the northern section, thereby restraining excessively long views.
- The 300 metre section of Ottery Road, within the school zone (between Innis Road and...
Tarley Road), was raised and textured in order to contrast with the tarred road surface on the balance of the route (Refer to Figure 2). The raised zone was constructed using interlocking paving blocks, which gave both an audible and a visual indication of the change in environment. The raised zone was designed to have an elevation of 100 mm above the normal road surface. The ramp length of between 1 and 1.5 metres was specified. Signage was provided to inform motorists of the raised zone. A signalised "push button" pedestrian crossing was located within this zone.

- The dangerous tree stumps were removed. New trees/shrubs were planted along the pedestrian paths/ sidewalk. The trees were located bearing in mind the sight distance requirements from intersecting side streets.
- Raised intersections were built at two other intersection locations (Refer to Figure 3). The raised intersections were also constructed using interlocking paving blocks. Signage was provided to inform motorists of the raised intersections.
- Lighting was provided, where current illumination was insufficient.

In addition to the above strategies and devices, a signalised intersection was introduced approximately halfway along the route, as signals were warranted at this location (Park Road).

**After Study**

Traffic data for the post implementation period was collected during July 2000, in the form of intersection turning movement counts and travel time surveys. These surveys were conducted during the same peak and off peak periods. Accident data for the route was again obtained from the Local Authority. The traffic flow data for the route is summarised in Table 6. Peak hour two way link flows on Otter Road were found to have decreased during all peak hours under consideration.

**Table 6: Traffic Flow Data for Otter Road: After Implementation**

<table>
<thead>
<tr>
<th>Section of the Route</th>
<th>Hourly Two Way Traffic Flow (Vehicles per hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekday AM</td>
</tr>
<tr>
<td></td>
<td>Two Way Flow (veh/hr)</td>
</tr>
<tr>
<td>Northern Section</td>
<td>937</td>
</tr>
<tr>
<td>Southern Section</td>
<td>1 172</td>
</tr>
<tr>
<td>Estimated AADT for the Entire Route</td>
<td>10 025 vehicles per day</td>
</tr>
<tr>
<td>Estimated Yearly Flow for the Entire Route</td>
<td>3.45 million vehicles per year</td>
</tr>
</tbody>
</table>

It was noted that while bus flows remained constant, the number of taxis using the route decreased substantially after the implementation of the traffic calming devices. This may be attributed partially to the relocation of the off peak holding area for taxis to Prince George Drive, which would have resulted in fewer taxis needing to use Ottery Road.
A summary of the recorded average and 85th percentile speeds for various sections of the route are indicated in Table 7.
Table 7: Average and 85th Percentile Vehicular Speeds on Sections of the Route: After Implementation

<table>
<thead>
<tr>
<th>Section</th>
<th>Direction</th>
<th>Weekday AM Peak Hour</th>
<th>Weekday Off Peak Hour</th>
<th>Weekday PM Peak Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Average Speed</td>
<td>85th % Speed</td>
<td>Average Speed</td>
</tr>
<tr>
<td>Between Tyrone Road &amp; Essex Road</td>
<td>NB</td>
<td>29.88</td>
<td>37.25</td>
<td>33.96</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>29.19</td>
<td>38.66</td>
<td>32.27</td>
</tr>
<tr>
<td>Between Essex Road &amp; Park Road</td>
<td>NB</td>
<td>28.59</td>
<td>30.30</td>
<td>30.07</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>38.83</td>
<td>40.42</td>
<td>31.12</td>
</tr>
<tr>
<td>Between Bath Road &amp; Prince George Drive</td>
<td>NB</td>
<td>26.10</td>
<td>31.05</td>
<td>31.31</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>27.74</td>
<td>28.72</td>
<td>29.73</td>
</tr>
<tr>
<td>Entire Route: Byrnes Road to Prince George Drive</td>
<td>NB</td>
<td>26.85</td>
<td>30.51</td>
<td>28.89</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>22.39</td>
<td>28.83</td>
<td>28.17</td>
</tr>
</tbody>
</table>

A comparison of the before and after average speeds over the various sections of the route (where raised intersections were installed) and over the entire route, is summarised in Table 8. A statistical comparison of the significance of the recorded differences in the average travel speeds is summarised in Table 9. A difference of two means test (t test) for small samples was used to determine the significance of recorded differences in the average speeds.

Table 8: Comparison of Before and After Average Speeds

<table>
<thead>
<tr>
<th>Section</th>
<th>Direction</th>
<th>Average Space Mean Speeds (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weekday AM Peak Hour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Before</td>
</tr>
<tr>
<td>Between Tyrone Road &amp; Essex Road</td>
<td>NB</td>
<td>35.87</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>49.70</td>
</tr>
<tr>
<td>Between Essex Road &amp; Park Road</td>
<td>NB</td>
<td>49.96</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>49.96</td>
</tr>
<tr>
<td>Between Bath Road &amp; Prince George Drive</td>
<td>NB</td>
<td>41.44</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>43.20</td>
</tr>
<tr>
<td>Entire Route: Byrnes Road to Prince George Drive</td>
<td>NB</td>
<td>42.31</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>45.38</td>
</tr>
</tbody>
</table>
Table 9: Statistical Comparison of Before and After Average Speeds

<table>
<thead>
<tr>
<th>Section</th>
<th>Direction</th>
<th>t Statistic</th>
<th>Statistically Significant Difference at Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Weekday AM Peak Hour¹</td>
<td>Weekday Off Peak Hour²</td>
</tr>
<tr>
<td>Tyrone Road to Essex Road</td>
<td>NB</td>
<td>1.70</td>
<td>4.64</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>5.24</td>
<td>8.60</td>
</tr>
<tr>
<td>Essex Road to Park Road</td>
<td>NB</td>
<td>21.30</td>
<td>34.89</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>16.58</td>
<td>23.01</td>
</tr>
<tr>
<td>Bath Road to Prince George Dr</td>
<td>NB</td>
<td>6.84</td>
<td>9.63</td>
</tr>
<tr>
<td></td>
<td>SB</td>
<td>14.05</td>
<td>16.38</td>
</tr>
<tr>
<td>Entire Route: Byrnes Road to</td>
<td>NB</td>
<td>2.00</td>
<td>4.31</td>
</tr>
<tr>
<td>Prince George Dr</td>
<td>SB</td>
<td>1.58</td>
<td>3.29</td>
</tr>
</tbody>
</table>

Notes: 1. 18 degrees of freedom \( t_{95} = 1.734, t_{99} = 2.552 \)
2. 15 degrees of freedom \( t_{95} = 1.752, t_{99} = 2.602 \)
3. 16 degrees of freedom \( t_{95} = 1.746, t_{99} = 2.583 \)

Based on the above assessment, the reduction in speeds over the raised intersections and over the entire length of the route are in general, highly significant (greater than 95% confidence level). Exceptions to this may be explained by high variances in the particular data set.

Before and after accident data that was obtained for the route is summarised in Table 10. Also indicated in Table 10 are the average accident rates per accident severity/type per 100,000 vehicles, for both before and after the implementation of the traffic calming strategies.

Table 10: Summary of Annual Accident Statistics for the Route (1998 to 1999) and Comparison of Before and After Accident rates

<table>
<thead>
<tr>
<th>Accident severity/type</th>
<th>Annual number of accidents by type</th>
<th>Average annual accident rate per 100,000 vehicles</th>
<th>% Reduction in annual accident rate/100,000 vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>Serious</td>
<td>2/0</td>
<td>0/0</td>
<td>0.05</td>
</tr>
<tr>
<td>Slight</td>
<td>20/4</td>
<td>5/4</td>
<td>0.48</td>
</tr>
<tr>
<td>All Accidents</td>
<td>108/13</td>
<td>20/16.5</td>
<td>2.63</td>
</tr>
</tbody>
</table>
Summary of Findings & Conclusions

The combined installation of traffic calming devices/strategies and the introduction of a signalised intersection along Ottery Road has resulted in the following impacts on the operational characteristics of the route:

- The treated sections of the route have experienced significant reductions in average vehicular speeds during commuter peak hours and during off peak hours.
- The 85th percentile speeds along the route have reduced to values well below the posted 60 km/hr speed limit.
- Vehicular flows have reduced, thereby indicating that the reduced speeds on the route have resulted in a diversion of some traffic to parallel routes, in particular Prince George Drive and Broad Road.
- Taxi flows have decreased substantially. This can partially be attributed to the stricter control on the number of licenced taxis on the route, the possible rerouting of taxis to a new holding area off Prince George Drive or some taxis have diverted due to the lower operating speeds.
- The frequency of accidents has been reduced by approximately 80%, while the frequency of slight injury accidents has reduced by approximately 70%. Over the past two years, the occurrence of serious injury accidents appears to have been eliminated.

The integrated urban design and traffic engineering approach to this project has resulted in a route which is appropriately designed for all users. The landscaped areas and raised intersections offer a visual quality to the route which communicates to drivers the type of environment they are in and the need within certain environment to be aware of the safety of other users.

References


Exhaust emissions and fuel consumption in residential areas with different characteristics

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Abstract
The objective of the study was to examine the connection between street characteristics in built-up residential areas and fuel consumption and exhaust emissions. The aim was to find emission and fuel consumption factors not only per kilometre, as traditionally used, but also for other characteristics such as different types of streets, street configuration, junctions and speed humps. Three configurations were studied in five different neighbourhoods situated in Sweden. For the emission and fuel consumption calculations a study using the chase-car method provided real traffic driving patterns from the different areas. Two different driving cycle simulation models were used to calculate vehicular emissions (CO, HC and NOx) and fuel consumption. The results from the simulation models were analysed through linear regression analysis. The results showed not surprisingly, that larger streets add somewhat less to pollution than smaller streets. The analyses however also showed that junctions and speed humps passed had a reducing effect on most pollutants. The reductions for humps were around ten times the reduction for junctions. The reducing effect of one speed hump was as much as 100 meters driven on a larger residential street. The study also made it clear the importance of having a broad view on the traffic situation when analysing environmental effects of traffic planning. Conclusions that could be drawn from these results were that junctions and especially speed humps encourage a driving pattern that has a reducing effect on vehicle emissions and fuel consumption. This has implications for traffic planning where regard should be taken to traffic safety as well as environmental concerns. The reducing environmental effect of speed humps, and to a certain degree also junctions, showed that they have a wider impact on the driving pattern than usually assumed.