Proceedings of the Conference

Road Safety on Three Continents

International Conference in Moscow, Russia,
19–21 September, 2001

Part 2
Proceedings of the Conference

Traffic Safety on Three Continents

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Preface

The international conference Traffic Safety on Three Continents in Moscow, 19–21 September 2001, was organised jointly by the Swedish National Road and Transport Research Institute (VTI), the State Scientific and Research Institute of Motor Transport in Moscow (NIIAT), U.S. Transportation Research Board (TRB), the South African Council for Scientific Industrial Research (CSIR), South Africa, and Forum of European Road Safety Research Institutes (FERSI).

The Moscow conference was the 12th in this conference series. Earlier annual conferences have been held in Sweden, Germany, France, the United Kingdom, the Netherlands, Czech Republic, Portugal and South Africa.

Conference sessions covered a number of road traffic safety issues:
- Advanced road safety technology
- Road safety audits
- Policy and programmes
- Traffic engineering
- Vulnerable and old road users
- Alcohol, drugs and enforcement
- Human performance and education
- Behaviour and attention
- Data and models
- Cost and environment
- Speed and speed management

Linköping in November 2001

Kenneth Asp
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OLDER DRIVER HIGHWAY DESIGN:  
The development of a handbook and training workshop to design safe road environments for older drivers

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Abstract

Older drivers are involved in significantly more serious injury and casualty crashes per kilometre driven than younger drivers and this rate is expected to increase as older people drive more and the population ages. Road design plays a major role in road safety, however, has generally not taken the older road user into consideration. There is therefore a need to take effective action to reduce risk levels to older road users by designing roads that accommodate the needs and capabilities of this vulnerable road user group. This paper describes a research program that examines the suitability of road design in Australasia for older drivers. The findings from an older driver crash ‘black-spot’ site study highlight the difficulty experienced by older drivers of selecting safe gaps at intersections which is exacerbated by factors such as limited sight distance, high task complexity, high traffic volumes, high approach speeds and wide, multi-lane carriageways. Some recommendations are made to target this problem for older drivers including replacing stop and give-way signs with fully controlled traffic signals, provision of roundabouts, and provision of fully controlled right-turn phases (left-turn in US and some European countries). A handbook and training package are under development to promote these recommendations to ensure they receive maximum use by Australasian road authorities and provide awareness of the difficulties experienced by older drivers.

INTRODUCTION

The absolute number of older driver crashes is currently not a large road safety issue in most Western societies, compared with other age groups such as young drivers aged 18 to 25 years. Moreover, drivers aged 65 years and over are commonly perceived as cautious and relatively safe drivers. The overall number of older driver crashes, however, obscures the magnitude of the older driver problem. There are relatively fewer older drivers compared to younger drivers on the road, and their total annual distance travelled tends to be less. Thus, when crash statistics are adjusted to take account of the distance travelled, the safety of older drivers is clearly an issue of concern. Figure 1 shows the number of serious injury crashes per billion kilometres travelled by age group for Australian drivers with and without adjustment for differences in physical vulnerability. The data indicate that both younger and older drivers have high levels of crash involvement compared to other age groups, even after controlling for differences in exposure and vulnerability. International figures show similar trends.
Moreover, this rate is expected to increase as older people drive more and the population ages. The proportion of persons aged 65 years and older in the Australian community is increasing more rapidly than any other age group and is predicted to increase from 11.1% in 2001 to 24.2% in 2051. Furthermore, the ‘old-old’ generation will become a more substantial sector of the population in the future, with predictions of a four-fold increase in the proportion of persons aged 85 years and over (Australian Bureau of Statistics, 1999). On the basis of growth in the older population, older driver safety is likely to become a larger issue in the years ahead, in part, as a consequence of the increased number of older potentially more mobile drivers in the community. These changing demographics highlight the magnitude of the future problem and promote a sense of urgency to better understand the crash risk of older adults and the role that road design can play in reducing this risk.

**Age-related changes and the impact on ability to drive safely**

Older drivers have distinct and different crash and traffic violation patterns compared to younger drivers. The causes of older driver crashes are undoubtedly complex and poorly understood, however, it is often argued that the over-involvement of older adults in crashes is largely a consequence of their behaviour in traffic and their ability to cope with traffic situations (Cooper, Tallman, Tuokko & Beattie, 1993; Benekohal, Michaels, Shim & Resende, 1994; Eberhard, 1996). Eberhard (1996) argued that behaviours that lead to older people’s crashes seem to be related to inattention or slowed perception and responses than to deliberate unsafe actions that are more common to younger drivers, such as speeding, and drinking and driving. In heavy traffic, at night on poorly marked roads, at complex intersections or in a potential crash situation, the demands placed on older drivers can exceed their abilities to avoid a crash.

Safe and efficient driving requires the adequate functioning of a range of abilities and loss of efficiency in any function can reduce driving performance and increase risk on the road. The task of driving is becoming a greater challenge for all motorists and this challenge increases...
exponentially with age. Unfortunately, as age increases, many abilities decline and health conditions become more common. There are a number of excellent reviews of functional impairments and health issues and the relationship with driving, particularly those by Janke (1994), Marottoli (1996), and Marottoli, Richardson, Stowe, Miller, Brass, Cooney and Tinetti (1998). The most pronounced effect of ageing for all people is the loss of sensory, cognitive and motor skills with advancing years. While there are many individual differences in the ageing process, even healthy adults are likely to sustain some degree of impairment. These losses include the following:

- declines in visual acuity
- declines in contrast sensitivity
- visual field loss
- reduced dark adaptation and glare recovery
- loss of auditory capacity
- reduced perceptual performance
- reductions in motion perception
- declines in attention capacity
- declines in cognitive processing ability
- decision time deterioration
- loss of memory capacity
- neuromuscular and strength loss
- postural control and gait changes
- slowed reaction time

The contribution of road design to older driver crashes

It appears that the complexity of the road environment can place increasing demands on an older driver’s adaptability, whilst ageing diminishes the capacity to cope with such situations. Worldwide crash data suggests that complex intersections are particularly troublesome for older drivers (Stamatiadis, Taylor & McKelvey, 1991; Benekohal et al., 1994; Staplin, Harkey, Lococo & Tarawneh, 1997; Fildes et al., 2000). Others, too, have reported that rear-end collisions, crashes at signalised intersections, crashes while merging and during backing manoeuvres and turning across traffic are common forms of crash involvement for older drivers (Garber & Srinivasan, 1991; Transportation Research Board, 1992; McKnight, 1996). Complex traffic situations may lead to difficulty in making appropriate decisions for older drivers because they must integrate and process many sources of information and act on that information.

It is important to recognise that the road transport system has, in general, not explicitly taken the older driver into consideration. Road design manuals, both in Australia and internationally, outline design criteria for the geometric design of roadways, and are based on available literature and sound engineering principles and practice. However, for the most part, these criteria are set from standards based primarily on measures of performance of the 85th percentile of the driving population, i.e., young and healthy males (Waller, 1991). Little, if any, consideration is made for drivers with disabilities, including age-related changes and health disorders, yet these changes can markedly affect these drivers’ ability to interact safely with their environment.

A US committee (Transportation Research Board, 1988) recognised over a decade ago that the roadway can be better designed to accommodate the needs and abilities of older road users. This committee concluded that present sign visibility and maintenance standards used in intersection
design and traffic operations are inadequate and fail to account for the capabilities of older road users. Fildes, Lee Kenny and Foddy (1994) found that older Australian drivers complain about the lack of consideration given to their special needs in road signing, lighting condition, merging lanes, pedestrian crossings and pavement surfaces. More recently, The Federal Highway Administration (FHWA) in the US has been working towards a Highway Design Manual that provides recommendations to road features including intersections and interchanges, road curves, passing zones and construction zones that take note of the special needs of older drivers (Staplin, Lococco & Byington, 1998).

Road design for older drivers in Australasia

The Monash University Accident Research Centre has undertaken a two-staged project to review the suitability of current road design requirements for older drivers in Australasia and to develop a handbook and training workshops for road and traffic engineers to design safe road environments for older drivers.

The first stage of this research program sought to explore whether current Australasian road design standards suit older drivers and whether there are aspects of these standards that should be changed in light of the anticipated increasing older population. It involved four phases including a literature review, an analysis of the FHWA’s Highway Design for Older Driver Handbook (Staplin et al., 1998), a one-day expert workshop and investigations of older driver crash black-spot sites. Detailed descriptions of these phases can be found in Fildes et al (2000) and are summarised below.

Review of literature and FHWA’s Older Driver Highway Design Handbook

The FHWA’s handbook makes 90 recommendations for highway design change in the US to suit older drivers and their diminishing sensory and cognitive capacities. At-grade intersections are the top priority in this handbook because intersections are the most problematic road feature for older driver crash risk. Next, difficulties with merging/weaving and lane changing operations are focussed on because older drivers experience difficulties with these manoeuvres. Last, roadway curvature, passing zones and construction zones are included because these road features can heighten tracking (steering) demands and may increase drivers’ workload, and there is an increased potential for unexpected events requiring a swift driver response.

Discussion of applicability of FHWA recommendations to Australasian roads

A committee of Australasian experts in the field of road design, road safety and human factors and ageing was organised to discuss the recommendations made by the FHWA and consider the desirability of changes in road design criteria to accommodate older drivers in Australasia. The FHWA’s recommendations were aggregated and refined into 45 individual recommendations that were considered applicable to Australasian roads and these were classified into four ‘importance’ categories related to implementation (Table 1).

Recommendations that were considered necessary to implement immediately in Australasia included i) multiple advance signing at minor and major interchanges, ii) advance warning of
stop signs with poor visibility, and iii) fixed lighting at locations where high pedestrian volumes and/or complex manoeuvres occurred. Some examples of recommendations, while seemingly desirable, but required further research and development before implementation included i) unrestricted sight distance and right-turn intersections (left-turn in the US and European countries), ii) increased contrast between painted edge of road, iii) separate signals to control movements in each turn lane of traffic, iv) increased letter height on signs, and v) suitability of traffic signal lamps for older drivers.

Table 1: Summary of classifications of the importance of road design features for Australasian roads.

<table>
<thead>
<tr>
<th>Response Categories</th>
<th>Proportion</th>
</tr>
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<tbody>
<tr>
<td>The recommendation is not suitable for Australasia</td>
<td>2%</td>
</tr>
<tr>
<td>The recommendation already exists in Australasian Road Design Guidelines</td>
<td>16%</td>
</tr>
<tr>
<td>The recommendation should be implemented immediately in Australasia</td>
<td>20%</td>
</tr>
<tr>
<td>Further research and development is required before this recommendation should be implemented</td>
<td>62%</td>
</tr>
</tbody>
</table>

Older driver black-spot crash site investigations

To further examine the relationship between road design features (believed to influence the safety of older drivers) and the older driver1 crash experience in Australasia, a crash investigation study was undertaken. Sixty-two older driver black-spot crash sites in four jurisdictions (Tasmania, Victoria, Queensland and New Zealand) were selected for analysis to explore the potential for road design features to prevent common older driver crashes in Australasia and to provide further evidence for prioritising road design features for implementation.

Older driver black-spot sites were selected using crash data supplied by each jurisdiction. Locations were ranked according to the number of crashes involving older drivers (crashes involving at least one older driver). From the list of high older driver crash locations, a sample of sites was selected for closer examination. This method was used in order to investigate crashes across a range of rural and urban locations including metropolitan locations. A strategic crash analysis was conducted at each black-spot site in each of the four jurisdictions. For each black-spot site data were collected relating to each older driver crash that occurred there in the last 5 years. The Police supplied accident report forms and collision diagrams for each of the crashes that occurred. A research team comprising an engineer, human factors psychologist and road safety expert reviewed this information and summarised the potential contributing factors to

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1 Older drivers have been defined here as drivers aged 65 years and older.
each crash as well as the culpability of those involved. Following this, the team visited the crash location and completed a structured questionnaire that examined the road design characteristics of the location. The probable involvement of road design features associated with each recommendation in older driver crashes at these sites was assessed during the site analysis. The assessment of road design features took into account the following:

- The main problem factors for older drivers at each of the black-spot crash sites,
- The potential for each road design feature to have contributed to the older driver crashes;
- Whether implementation of the road design features would have prevented the crashes at each location, and
- The importance of each road design feature weighted and ranked in order of potential contribution.

The vast majority of older driver black-spot crash locations were intersections, some of which appeared to present serious crash problems for older drivers, while some other intersections displayed spatially dispersed crash experience with no clear patterns. Figures 1 and 2 show some examples of the types of intersections inspected in this analysis. They demonstrate that older drivers experience problems at complex intersections with poor sight distance, high volumes of traffic and high speeds. Crashes involving older drivers also often occur as the older driver is attempting a complex manoeuvre such as making a right-turn (left-turn in the US and European countries) across traffic without the aid of right-turn phase signal control.

Figure 1: A complex intersection with partial control of right-turning traffic, allowing filtered right-turns.

Figure 2: An intersection controlled by stop signs with poor sight distance.

The single, most significant and robust finding of this study was that the principal problem for crash-involved older drivers was selecting safe gaps in conflicting traffic when making decisions at intersections. This basic problem manifest itself mainly at intersections controlled by stop or
give-way signs, or at intersections controlled by partial control of right-turn manoeuvres. At all controlled intersections, the gap selection task for older drivers was often exacerbated by a number of additional factors. These factors and their estimated contribution to crash risk are summarised in Table 2.

Table 2: Contributing factors to older driver crash risk at intersections.

<table>
<thead>
<tr>
<th>Contributing Factor</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap Selection</td>
<td>58%-85%</td>
</tr>
<tr>
<td>Limited sight distance</td>
<td>20%-45%</td>
</tr>
<tr>
<td>High task complexity and the presence of other road users</td>
<td>25%-73%</td>
</tr>
<tr>
<td>High traffic volumes</td>
<td>7%-80%</td>
</tr>
<tr>
<td>High approach speeds of conflicting traffic</td>
<td>25%-73%</td>
</tr>
<tr>
<td>Wide, multi-carriageways to be negotiated</td>
<td>13%-33%</td>
</tr>
</tbody>
</table>

A major focus of the crash analysis was to identify the likely role that the proposed changes in highway design specifications played in older driver crashes. The purpose of examining this relationship was to define possible theoretical links between road design features and the probable contributing factors to older driver crashes. Thus, the likely (probable involvement) of each factor was assessed at each black-spot crash site and summed to provide overall results. The assessment of road design features took into account the following:

- The main problem factors for older drivers at each site,
- The potential for each road design feature to have contributed to these crashes,
- Whether implementation of the road design features would have prevented the crashes at each location,
- The importance of each road design feature weighted and ranked in order of potential contribution. [This figure was calculated according to the percentage of sites, where the given design feature was theoretically applicable or relevant, and the percentage of sites where the given road design feature was considered to have actually contributed to the main crash pattern at that site³].

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² For each crash site, the research team estimated whether the suggested road design feature could have been applied at that location (applicability) and also whether it could have had the potential to prevent the crash (probability).

³ The weighted figure (for each road design feature) was calculated by multiplying the applicable % by the probable %.
The top ten road design features ranked according to their applicability and probable contribution to older driver crashes at the sites investigated are listed in Table 3.

### Table 3: Road design features ranked according to the applicability and probable contribution to older driver crashes.

<table>
<thead>
<tr>
<th>Road design feature</th>
<th>Overall</th>
<th>Weighted Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applicable</td>
<td>Probably</td>
</tr>
<tr>
<td>Could a lack of the use of separate signals to control movements in each turn lane have contributed to the crashes?</td>
<td>50%</td>
<td>45%</td>
</tr>
<tr>
<td>Could restricted sight distances at right-turn intersections have contributed to the crashes?</td>
<td>68%</td>
<td>33%</td>
</tr>
<tr>
<td>Could a perception-reaction time distance for ISD’s of &lt;2.5 sec have contributed to the crashes?</td>
<td>90%</td>
<td>25%</td>
</tr>
<tr>
<td>Could a restricted sight distance and lack of right-turn offsets for stop-control and right-turn have contributed to the crashes?</td>
<td>66%</td>
<td>15%</td>
</tr>
<tr>
<td>Could the absence of minimum receiving lane width of 3.6m with 1.2m shoulder width have contributed to the crashes?</td>
<td>61%</td>
<td>13%</td>
</tr>
<tr>
<td>Could the absence of treatments to prevent drivers choosing wrong lanes have contributed to the crashes?</td>
<td>48%</td>
<td>17%</td>
</tr>
<tr>
<td>Could unsuitable traffic signal lamps have contributed to the crashes?</td>
<td>34%</td>
<td>24%</td>
</tr>
<tr>
<td>Could a lack of minimum sight distance of 215m above 65km/h have contributed to the crashes?</td>
<td>18%</td>
<td>36%</td>
</tr>
<tr>
<td>Could a lack of lane-use control signs plus lane-use arrow road markers have contributed to the crashes?</td>
<td>56%</td>
<td>9%</td>
</tr>
<tr>
<td>Could a lack of left-turn channelisation with provision of adjacent pedestrian refuge at left-turn slip lane have contributed to the crashes?</td>
<td>35%</td>
<td>14%</td>
</tr>
</tbody>
</table>

As a result of defining these links and assessing the relative importance of each road design feature, opportunities for improvements to road design standards to enhance older driver safety were identified. It was concluded that road design enhancements which focus on the following issues have the potential to reduce crash, and possibly injury, risk for older drivers:

- **Improve sight distances** for older drivers at intersections controlled by stop or give-way signs,
• **Separate right-turn movements** performed by older drivers at traffic signals from opposing through movements,

• **Enhance the conspicuity** of traffic signal displays at signalised intersections, and

• Clearly **define permissible vehicle paths** and prevent wrong choices or use of traffic lanes at intersections.

As noted previously, the most robust finding in this study was that older drivers appear to experience problems in selecting safe gaps in complex traffic situations. It was concluded that road design measures that reduce the reliance of older drivers on declining gap selection abilities should receive high priority. The opportunity exists through enhancements to road design standards and practices to reduce older driver crash and injury risk in circumstances where safe gap selection is critical. While it is not possible to eliminate the gap selection task for drivers at all intersections, it is possible to modify, through road and traffic engineering design, the nature and risk associated with the gap selection task for older drivers. Suggested countermeasures to target this problem for older drivers could include:

• Replacing stop and give-way signs with fully controlled traffic signals in appropriate locations to lessen the decision-making task for older drivers,

• Provision of roundabouts – with roundabout control, older drivers need only select a gap in one direction of the traffic at a time. In addition, this countermeasure addresses problems with high speeds of approaching vehicles,

• Provision of fully controlled right-turn phases – this greatly simplifies the gap selection task for older drivers and addresses site-specific problems with limited sight distance, high traffic volumes and high speeds.

**Promotion of road design recommendations**

This stage of the research is designed to promote the set of road design recommendations relating to older driver safety in Australasia to ensure that they receive maximum use by road authorities. To do this, three tasks are currently underway and are summarised below.

**Older driver handbook**

An older driver handbook is currently under development. This will be a practical, easy-to-use guide for road designers and traffic engineers and contains information to design roads that will accommodate the needs and capabilities of older road users. Specifically, it contains the recommendations and guidelines highlighted in the first stage of this project. It also contains extensive sections covering the rationale and supporting evidence of age-related limitations and consequent crash risk for each recommendation.
Training Workshop
In addition to the handbook, a training workshop is being developed. The training workshop will provide road designers and traffic engineers with some awareness of the difficulties experienced by older drivers when using the road system. It will also promote the use of the handbook. Specifically, the objectives of the training workshop will be for road designers and traffic engineers to i) understand why an older driver road design handbook is needed, ii) understand the relationship between the handbook and existing design manuals, iii) understand age-related changes and how they can affect driving performance, and iv) learn what the handbook contains and how it can be applied.

Liaison with Australasian National road authorities
At this stage, the handbook contains road design information and recommendations that will help accommodate the needs and capabilities of older drivers. These recommendations, however, do not constitute a new standard of required practice. When and where designers apply each recommendation remains at their discretion as the expert practitioner. On-going consultation with the national road authority of Australasia (Austroads) is underway to assist in having the recommendations formally incorporated within national road design standards.

CONCLUSIONS
Road design plays a major role in road safety and it is suggested that the design of the road environment may contribute to the level of risk that older drivers face on the road, particularly because of the combination of complex road environments and diminished information processing abilities of older drivers. Moreover, as the population ages, it will become increasingly important to design roads that will accommodate the needs and capabilities of older road users. To address this problem, a research program is underway to recommend and promote road design features for implementation in Australasia that will accommodate older road users.

The analysis of older driver black-spot crash sites has identified that the principal problem for older drivers is selecting safe gaps in conflicting traffic at intersections and that this is exacerbated by other road and traffic features. A number of changes in road design features were highlighted in this process that have the potential to reduce crash risk for older drivers. These include improved sight distance at intersections, separate right-turn movements at traffic signals, enhanced conspicuity of traffic signal displays, and clear definition of permissible vehicle paths at intersections. In order to promote recommendations from this research and ensure that they receive maximum use by road authorities, a handbook and training workshops are being developed. These will provide the road design and engineering community with an awareness of the problems that older drivers face and information on the design recommendations.
REFERENCES


COULD ADHERENCE AND ROAD GEOMETRY BE USED TO IDENTIFY THE AREAS OF RISKS?

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SUMMARY

Although road traffic accidents rarely have a single cause, if we take into account the relative amounts of time pavements are wet rather than dry, twice the proportion of accidents occur on wet pavements. This paper uses a number of case studies to attempt to assess if adherence and road geometry could explain the increased risk during wet weather.

In recent years, the link between pavement surface characteristics and accident risk on wet pavements has been demonstrated by a number of authors from different parts of the world. The analysis conducted in the studies described in this paper confirms this link, without claiming to measure in absolute terms the effect on road safety of the factor considered (friction, texture or layout). Nevertheless, comparisons between case studies on routes with very different layouts and driving conditions show that:
- frictions and texture characteristics have the same type of effects on the accident rate on wet pavement, namely:
  - the accident rate tends to increase when the side friction coefficient or the macrotexture diminishes,
  - the change in the accident rate is not steady, but becomes much less below certain values.
- the curvature radius of the bends, on difficult road layouts, is an important factor of influence on the accident rate, and on the severity of these accidents.

INTRODUCTION

The general opinion on the extent to which adhesion has an effect on road safety, is far from being unanimous. It is important to remember that the cause of a road traffic accident is rarely due to one single factor. For accident specialists, driver behaviour is the main cause and the pavement surface is only one factor amongst others. For road engineers, adequate skid resistance on a wet pavement surface is highly important. In France, figures show that about 20% of accidents resulting in injury occur on wet pavements, whereas on average, pavements are only wet for about 10 to 12% of the time.

The central laboratory for roads and bridges (Laboratoire Central des Ponts et Chaussées) has participated in work on this subject, through the launching of a line of research from 1991 to 1993 (ESR 05). Within the scope of this line of research, several concrete case studies were carried out in order to analyse the effect of skid resistance on safety, assessed by means of a friction/force coefficient and a macrotexture value. The present article summarises the results of three of these studies, carried out on routes or locations with very different road layouts and traffic conditions:
- a major regional urban ring road, on which several techniques for the improvement of surface characteristics were tested,
- several sections of main roads linking several large urban areas in the Rhône-Alpes region,
- a section of a specific main road, chosen for its particularly difficult layout.

The data obtained from these studies are similar to those obtained in other studies quoted at the end of this article and to the results presented in publications of the World Road Congress in Marrackech (1991), in the session dedicated to pavement surface characteristics.
The decrease in road safety when pavement surfaces are wet has led to considerable research ([1] to [8]), on the analysis of the relationship between pavement surface characteristics and the rate of accidents. An illustration of the results of part of this research is given in figure 1, based on the bibliography produced by Mr Delanne (LCPC) and Mr Travert (MICHELIN) [9].

![Figure 1 Relationship Between The Risk Increase Coefficient And The Friction Coefficient Of The Pavement For Country Roads. The Risk Increase Coefficient Car Is The Ratio Between The Accident Rate On Wet Pavement For A Friction Coefficient (FC) Measured At 65 km/h And The Same Accident Rate When The Friction Coefficient (FC) Is Equal To 0.5.](image)

**A. Study Carried Out On A Regional Metropolitan Ring Road**

This ring road comprising a dual carriageway in each direction, 35 km in length, enables a North-South transit with a high proportion of HGV traffic. It also has to cope with heavy regional traffic and a considerable amount of local traffic between the town centre and the various suburbs or important public sites (airport, industrial complex, universities) in this urban area. The speed limit on this ring road is 110 km/h and in 1992, the average daily traffic had reached 38 000 vehicles in each direction.

A study was carried out during the period 1985-1994. From 1988 to 1990, the wearing course of the whole of the ring road was renewed [10]. Various solutions were retained for this maintenance work: skidabrader, asphalt concrete [11], recycled asphalt concrete, porous asphalt concrete (PAC) [12], very thin asphalt concrete (VTAC) [13]. The aim of this relatively wide choice was to examine how each of the immediate improvements of the surface characteristics, brought about by each solution, would wear over time, and their impact in terms of the reduction in road traffic accidents.
The main objective of the study consisted in studying the impact, in terms of accidents, over a certain number of years, according to the different surface characteristics of the various wearing courses present on this ring road.

Amongst other things, this required:

- the collection and the analysis of accidents resulting in injury, between 1985 and 1994,
- a summary of the engineering and maintenance work carried out on the pavement surfaces,
- periodic skid resistance measurements:
  - with the SCRIM device (sideway force coefficient, SFC) [14]
  - with the ADHERA device (braking force coefficient, BFC) [15] and [16],
- the collection and the analysis of climatic data over the given period of time,
- statistical analysis of the results prior to and after applying the different wearing courses.

The data related to accidents were expressed as an « accident rate » \( A_r \), equivalent to the average annual value, per kilometre and per vehicle, of the number of accidents noted on a given section of road, multiplied by \( 10^8 \), or:

\[
A_r = \frac{n_{acc}}{n_{veh} \Delta t \cdot L} \cdot 10^8,
\]

with:

- \( n_{acc} \) representing the number of accidents during the observation period,
- \( \Delta t \) representing the duration of the observation period, expressed in days,
- \( n_{veh} \) representing the daily number of vehicles (annual average)
- \( L \) length of the pavement surface studied (km).

Skid Resistance Modifications Over The Period 1985-1994

- Sideway force coefficient (SFC) values
  An analysis was made of a number of surfaces presenting SFC varying from 0.45 to 0.65, according to the nature of the pavement surface and its state of wear. The sections examined were approximately 5 km in length (length related to maintenance work carried out).

  This analysis showed that under the effect of traffic and whatever the wearing course applied, the value of the average SFC had decreased by 0.08, three years after the surfaces were applied.

- Braking force coefficient (BFC) values
  An analysis was made on a number of surfaces presenting BFC varying:
  - from 0.34 to 0.43 for the BFC, measured at 40 km/h (BFC_{40}),
  - from 0.13 to 0.32 for the BFC, measured at 110 km/h (BFC_{110}).

  After 4.5 years of traffic, and for all the techniques studied, a decrease in the braking force coefficient values could be noted. This decrease is much higher for the BFC_{40} than for the BFC_{110}. Depending on the surface, it was therefore noted that over this period:
- for the PAC and VTAC, the BFC\textsubscript{40} and the BFC\textsubscript{110} increase over the first six months (erosion of the bituminous film), followed by a regular decrease thereafter. This decrease represents:
  - 0.09 (PAC) and 0.19 (VTAC) for the BFC\textsubscript{40},
  - 0.06 (PAC) and 0.07 (VTAC) for the BFC\textsubscript{110};
- for the skidabrader asphalt concrete, contrary to the PAC and the VTAC, the first six months of traffic corresponded to a considerable decrease (-0.13) for the BFC\textsubscript{40} as for the BFC\textsubscript{110}. After this period of rapid change, for the same period (1990 to 1994), the following decreases were noted:
  - 0.11 for the BFC\textsubscript{40},
  - 0.08 for the BFC\textsubscript{110},
values roughly similar to those noted for the other techniques (figures 2 and 3).

![Figure 2. Evolution Of The Braking Force Coefficient BFC\textsubscript{40}, On The Ring Road Of A Regional Metropolis, (Average Traffic: 38 000 Vehicles Per Day And Per Direction).](image1)

![Figure 3. Evolution Of The Braking Force Coefficient BFC\textsubscript{110}, On The Ring Road Of A Regional Metropolis (Average Traffic 38 000 Vehicles Per Day And Per Direction).](image2)

For the period 1990-1994, regardless of the technique, and without taking into account the modifications of the first months, the following average values can be noted:
  - a decrease of 0.13 for the BFC\textsubscript{40},
  - a decrease of 0.07 for the BFC\textsubscript{110}.  

As the effect of microtexture on skid resistance is more noticeable on friction coefficient measurements taken at a low speed (and macrotexture more noticeable on friction coefficient at high speed), this difference in the modification of friction coefficients, can be interpreted, at a first glance, by the fact that aside from any structural evolution, the microtexture of a pavement surface evolves more rapidly under the effect of traffic, than does macrotexture.

**Relationship Between The Skid Resistance, Assessed By The Sideway Force Coefficient SFC, And The Accident Rate On A Wet Pavement.**

Depending on the sections of pavement where the road works were carried out, the observation period 1985-1994 was divided into three periods of 2.5 to 3 years, excluding the year during which the road works were carried out. For each of these periods, the skid resistance was assessed according to the results of the sideway force coefficient (SFC) measurements taken by the SCRIM device.

For each section of road works covering a length of about 5 km, the average SFC value for each of the three periods previously defined was calculated. A histogram was drawn up of the SFC measured on the entire ring road for the three times that the SCRIM device passed over the pavement surface. For each accident noted on a wet road, we applied the average SFC value calculated for the corresponding section of road, after the reading of the SCRIM device that was the nearest to the date of the accident.

We were then able to draw up the histogram of the SFC values on the accident-prone sections of road. For each type of SFC, these elements enabled us to calculate the accident rate on a wet pavement surface for $10^8$ vehicles $\times$ km per year ($A_r$).

Poisson’s law applied to the number of accidents enabled us to calculate a 90% confidence interval of the average rates calculated in this manner.

Figure 4 illustrates the relationship between the SFC values and the accident rate values. A significant increase for accident rates on the pavement sections with the lowest skid resistance values can be noted.

![Figure 4 - Relationship Between The Average Sideway Force Coefficient (SFC) And The Rate Of Accidents Resulting In Injury On A Wet Road On A Regional Metropolitan Ring Road (130 km; 82 Accidents).](image-url)
B. Studdies Carried Out In The Rhône-Alpes Region

Studies were carried out on four routes involving main roads, joining several metropolitan areas of the Rhône-Alpes region two by two, and each dealing with traffic of about 10,000 vehicles per day. These four routes represent a total length of 215 km, on which the national accident file gave mention of 201 accidents resulting in injury, on a wet pavement surface over a period of 4.5 years.

For each of these studies we used the skid resistance and macrotexture measurements taken by the SCRIM device, equipped with the RUGO ([17], [18]). The RUGO uses a laser sensor that carries out the reading for a profile, enabling an equivalent texture depth by sand patch test to be obtained by correlation and referred to as ETD (Estimated texture depth). For each portion of itinerary measuring 100 m in length, the lowest SFC and ETD values given every 20 meters by the devices, were noted.

Information concerning the nature of the wearing courses obtained through pavement/itinerary diagrams in the French national road data bank, enabled us to retain only the accidents that occurred on wearing courses that were actually in place when the SCRIM device readings took place. Based on all these elements, we were able to establish histograms for the distribution of sideway force coefficients (SFC) and texture depth by laser measurement values (ETD):

- on the whole of each itinerary (figures 5 and 6),
- on all the sections with at least one accident on a wet pavement surface (figures 7 and 8).

As the vast majority of sections studied had a sideway force coefficient between 0.4 and 0.8, we limited the following part of our analysis to the interval: 0.4 < SFC < 0.8.

The general statistic for French main roads at the same period (1989-1994, 50,000 km of roads) gives 2% of roads as having SFC < 0.4 and 4.3% of roads as having SFC higher than 0.8.

For the texture depth calculated by laser measurement (ETD), the sections studied where ETD < 0.2 only represent 0.75% of the routes and those higher than 1.2 represent 14.8%, over a wide interval. The analysis was therefore limited to the interval: 0.2 < ETD < 1.2.

This statistic is also similar to that for French national main roads.

For each of the different classes of SFC or ETD retained, we calculated the accident rate for $10^8$ véhicules × km/year, which gave figures 9 and 10, on which we transferred the 90% confidence intervals obtained using Poisson’s law. As the validated SFC and ETD measurements are not related to identical lengths, the reference systems for these two figures are not quite the same.

Figure 9 shows the existence of a threshold below which the accident rate on wet pavements distinctly increases. This threshold, at the limit between the classes [0.4-0.5] and [0.5-0.6], corresponds to a sideway force coefficient (SFC), of 0.50. For the SFC values higher than 0.50, the effect of the sideway force coefficient on the accident rate is insignificant (overlapping of confidence intervals).

Figure 10 also clearly shows the existence of a macrotexture threshold (characterised by an estimated texture depth value), below which the accident rate on wet pavements increases very rapidly: this threshold, at the limit between classes [0.2-0.4] and [0.4-0.6], corresponds to an ETD of 0.40.
Figure 5: Histogram of Sideways Force Coefficient (SFC) Values, On The Four Routes (208 km Of Validated Measurements).

Figure 6: Histogram of Texture Depth By Laser Measurements (ETD), On The Routes (210 km Of Validated Measurements).

Figure 7: Histogram of the Sideways Force Coefficient Values For All The Sections Of The Four Routes On Which At Least One Accident Resulting In Injury Occurred On A Wet Pavement Surface (201 Accidents).

Figure 8: Histogram of Values For Texture Depth By Laser Measurements (ETD), On All The Sections Of The Four Routes On Which At Least One Accident Resulting In Injury Occurred On A Wet Pavement Surface (185 Accidents).

Figure 9: Relationship Between The Sideways Force Coefficient And Accidents Resulting In Injury, Occurring On Wet Roads: 4 Main Roads (213 km, 201 Accidents).

Figure 10: Relationship Between Estimated Texture Depth ETD And Accidents Resulting In Injury, Occurring On Wet Pavement: 4 Main Roads (210 km, 182 Accidents).
C. Study Carried Out On A Road With Difficult Layout

The third study was carried out on a section of main road with a difficult layout, in the centre of France. This 13 km section of a two-lane road has to cope with daily traffic of 9 000 vehicles, 20% of which is made up of HGVs. The route is very sinuous, with very tight bends. This study was carried out over the period 1987 to 1993. During this period, skid resistance measurements were carried out seven times with the SCRIM device and accidents resulting in injury were noted and analysed.

The accident rate on a wet pavement for $10^8$ véhicules.km/year was calculated for all the sections with a curvature radius lower than 350 m. These rates are on average 4 to 5 times higher than in the first study example.

As in the first case, the reduction in the SFC value is accompanied by an increase in the rate of accidents noted, but this tendency is less noticeable than in the previous study (figure 11). This difference is probably due to the strong influence of the road layout compared to that of surface characteristics alone.

![Figure 11](#)  
**Figure 11**  Relationship Between The Sideway Force Coefficient (SFC), And Accidents Resulting In Injury, Occurring On A Wet Pavement : Main Road With Difficult Layout: (13 km, 41 Accidents)

In addition to an analysis of the influence of surface characteristics, we also examined the relationship between the horizontal curvature radius and the accident rate. Figure 12 shows that the accident rate on a wet pavement increases considerably on pavement sections with a low horizontal curvature radius.
In order to appreciate the seriousness of the accidents occurring in this location, for each accident occurring on a wet pavement surface, we calculated the number of people killed, seriously injured or suffering from minor injuries, by studying the costs resulting from each type of accident, calculated by the Département d’Exploitation Sécurité of the CETE de Lyon (estimation made in 1993):

- \( 244,000 \) € for a fatal accident,
- \( 22,100 \) € for a serious injury,
- \( 1,500 \) € for a minor injury,
- \( 2,100 \) € for an accident resulting in vehicle damage only.

On this difficult layout section of road, for which the sideway force coefficients (SFC), are between 0.45 and 0.65, over 7 years the following accidents were noted:

<table>
<thead>
<tr>
<th></th>
<th>Dry pavement</th>
<th>Wet pavement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of accidents</td>
<td>43</td>
<td>61</td>
</tr>
<tr>
<td>Fatal accidents</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Seriously injured</td>
<td>17</td>
<td>44</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>39</td>
<td>71</td>
</tr>
<tr>
<td>Vehicle damage only</td>
<td>8</td>
<td>33</td>
</tr>
</tbody>
</table>

The relationship between the sideway force coefficient (SFC), and the average cost of accidents resulting in injury noted on a wet pavement was calculated (figure 13).
The average cost was also compared to the value for the curvature radius of the accident zone (figure 14). This figure clearly shows that the lower the bend curvature radius, the more serious the accident on average.

These relationships between the accident rate and the sideway force coefficient, between the accident rate and curvature radius, and between the seriousness of accidents and sideway force coefficient, led to the conclusion that on a road with difficult layout, the factor triggering the accident often seems to be linked to the curvature radius of the bends. Low skid resistance then becomes a factor that worsens matters, by increasing vehicle impact speed and thus the seriousness of vehicle occupant injuries.
Conclusion

As was mentioned in the introduction, road traffic accidents are generally due to complex processes, combining the effects of several factors, amongst which figure driver behaviour and certain vehicle and infrastructure characteristics. The analyses carried out within the scope of the three studies presented in the present document, compare the relationship between one single variable only and the accident rate, and therefore do not claim to provide an absolute measurement of the influence of this variable (sideway force coefficient value, for example). However, the comparison of all these case studies, which correspond to different road layouts and traffic conditions, show that:

- friction and texture characteristics have a similar influence on the rate of accidents occurring on a wet pavement, notably:
  - the accident rate tends to increase when the SFC and ETD decrease,
  - the increase in the accident rate is not constant and increases sharply below certain values.

- the radius of the curves, on difficult layouts, is an important factor of influence on the accident rate, and on the severity of these accidents.

All these points could help to identify and locate the sections which present a risk for user safety. They could also enable the best diagnostic to be made and propose the best solutions for these sections.
Bibliography


SEVERITY OF RUN-OFF-CRASHES WHETHER MOTORWAY HARD SHOULDERS ARE EQUIPPED WITH A GUARDRAIL OR NOT

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Abstract

Context - On most French highways, hard shoulders are equipped with safety barriers to protect vehicles from running off the roadway from either punctual obstacles like bridge pillars, or in the presence of embankments or ditches for differences of level above 4 m. The research question is to determine if there would be a global safety gain to the user in systematically equipping all hard shoulders with safety barriers.

Methods - The severity of run-off the road is measured and compared according to if they occur with a protected hard shoulder or a non-protected one, and in the latter case, whether what is off the road is at the same level, an embankment or a ditch. The safety indicator used is the presence of at least one casualty inside the vehicle running off the road. A Logistic model is used to take into account all the different relevant cofactors.

Data - The data relates to five years of observation - 1996 to 2000. The network comprises approximately 2,300 km of motorway located in plains. Three quarters of these roads have two lanes in each direction and one quarter has three lanes. Average traffic is between 10,000 and 60,000 vehicles per day, 10 to 20% of which is trucks. A crash report form is completed whenever a vehicle on or off the motorway roadway cannot resume its journey without being towed away after a crash. All injury-crashes and damage-only crashes are recorded. Information is particularly detailed on the highway infrastructure and its part in the frequency and severity of accidents.

Results - The severity of run-off the road on hard shoulders is on average significantly higher in the absence of a safety barrier. Higher values of severity are connected with run-off the road in the presence of embankments or ditches (lower than 4 meters, as others have already systematically been equipped). These results take into account the typology of the accident (number of vehicles involved, different impacts, type of vehicle involved) and of highway characteristics. Despite there being less and less non equipped hard shoulders, severity differences are large enough to be significant, and confirm the results of previous research carried out from 1985 to 1995 on a part of the same network.

Conclusion - Systematic equipment of highway hard shoulders appears to be beneficial as a whole within the infrastructure and European traffic conditions, with a better control of run-off the road consequences. Moreover, the subsequent suppression of most of the ends of guardrails should also increase safety.

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Introduction

In France as in most Western European countries, motorways have 2 or 3 lanes, traffic flows are usually between 20,000 and 60,000 vehicles/day and the proportion of trucks varies between 10 and 20%. The width of the median strips is often only 3 to 5 meters. In these conditions of narrow median strips, most central reservations are equipped with a safety barrier in order to minimize the possible occurrence of crossover crashes (Martin & Quincy 2001). This means that the question is no longer whether it is relevant to equip them with a safety barrier or not, but rather what kind of barrier is the most efficient (Martin et al. 1997b).

On the contrary, policies concerning the equipment of hard shoulders on motorways vary widely between countries. In France, in accordance with national regulations, safety barriers are systematically used when the roadside is more than 4 meters below or above the level of the motorway roadway, or when a punctual obstacle, like a tree or a bridge pillar, is too close to the roadway (less than 10 meters). Within the framework of French legislation it was still possible to choose between different equipment policies; for our observed network, safety barriers are present whenever there is a ditch of 2.5 meters or more, or an embankment.

The question which must now be asked is: in order to improve the safety user, is it relevant to go further, i.e. to generalize this equipment policy to the whole hard shoulder, even if there is no obstacle or if the roadside is nearly at the same level? Note that to ask this question suppose going against the primary thinking which considers safety barriers as roadside hazards instead safety features (Micchie & Bronstad 1994). If we put the cost problem aside, we need to consider the different consequences of such an equipment policy, that is, on the positive side - a possible reduction of severity in case of impact against safety barrier, and a marked reduction of problems due to the ends of each barrier, and for the negative aspect a possible increase of crashes because of encroachments on the hard shoulder inducing impacts against barriers. These different issues will be examined in this study. Let us note that this question has already been raised in a previous work (Martin et al. 1997a), and that the aim of this present paper is to confirm or invalidate the previous results with more recent observations which correspond to an extended motorway network.

Objective

On most French highways, hard shoulders are equipped with safety barriers to protect vehicles running off the roadway either from punctual obstacles, or in the presence of embankments or ditches for differences of level above 4 m. The research question is to determine if there would be a safety gain to the motorway user in systematically equipping all hard shoulders with safety barriers.
Material

The data relates to five years of observation - 1996 to 2000. The network comprises approximately 2,300 km of motorways located in plains. Three quarters of these roads have two lanes in each direction and one quarter has three lanes. Average traffic is between 5,000 and 31,000 vehicles per day, with a mean of 22,000 for the two lanes, and between 18,000 and 70,000, with a mean of 52,000 for the three lanes. The percentage of trucks varies between 10% and 20%. Compared to a previous study (Martin et al. 1997a), the range of observed traffic flows has been increasing, as a majority of two lane motorways with low traffic has been added to the observed network.

A crash report form is completed whenever a vehicle on or off the motorway roadway cannot resume its journey without being towed away after a crash. All injury-crashes and damage-only crashes are recorded. Information is particularly detailed on the highway infrastructure and its part in the frequency and severity of accidents. The data recording system, then the coding of information, allows the trajectory of the vehicles involved in a crash to be analyzed in a succession of events, called impacts even when there is no real impact with objects but only an encroachment outside the paved roadway on a central reservation or a shoulder. A regularly updated database describes the setting up of different barriers, which allows the verification of the coherence of information provided for each crash with the knowledge we have of the road infrastructure.

Figure 1: Observed motorways - 1996-2000
Method

We can consider three types of crashes based on the location of first impact: the crashes that occur when at least one vehicle involved suffers a first impact on the shoulder, the crashes that occur when at least one vehicle involved sustains a first impact on the central reservation and the crashes, where the first impacts of the vehicles involved occur on the roadway.

For the main part of this study, the statistical unit used is the vehicle instead of the accident because it gives the opportunity to specifically address different factors associated with severity such as the presence of a barrier on the hard shoulder, or in the opposite case, the presence of an embankment or a ditch on the roadside.

More precisely, we distinguish shoulders with or without guardrails, and, for each type, we subdivide into the following categories. Concerning the equipped hard shoulders, we distinguish:

- the ends (or extremities) of the guardrails that we are concerned with, which are about 12 meters long,
- and the part of the guardrails disregarding the extremities, so-called length of need (Ross et al. 1993), which is the part, which functions, in good conditions for being an efficient shock absorber.

The distinction between the different types of safety barriers present on the hard shoulders is not made in the analysis, the vast majority of them being simple metallic guard rails with a level N2 average restraint capacity according to European standards (also called W-beam guardrails).

Concerning the hard shoulders without any guardrail, it is quite important to distinguish three cases according to the fact that the roadside can be on the same level as the roadway, that is to say with a difference in level of less than half a meter, or can be below road level or above road level. This does not concern roadsides with ditches higher than 4 meters, as they are already equipped, as are roadsides with punctual obstacles.

First we compare the Incidence Ratios for all crashed vehicles $IR_T$ according to whether hard shoulders are equipped with barriers or not. The numerator of these ratios is the number of vehicles involved in all the accidents and the denominator is the number of vehicles exposed (nve), estimated by:

$$nve = \sum_{sections} \text{mean daily traffic} \times \text{number of observation days} \times \text{observed length}$$

The summation is made on all homogeneous sections, i.e. continuously equipped with barriers on hard shoulders or not, which are identified by means of a part of our database describing all safety barriers put up along the roadway. Then we calculate the IR$_C$ for injury crashes, with the number of vehicles in which there is at least one casualty inside these vehicles. One phenomenon we can expect with the addition of safety barriers on hard shoulders is that it might cause an increase in the number of vehicles returning to the traffic lanes, and hence more secondary impacts with other vehicles. In order to take this possible problem into account, the vehicle sustaining the first impact on the shoulder will be considered as having suffered an injury crash if there is a casualty inside this vehicle, or inside the vehicle hit after the first impact, if any.
The comparison between two Incidence Rates goes through the calculation of their ratio, called CIF (Comparative Incidence Figure). The incidence rates are considered as significantly different if their 95% confidence interval does not include 1. The confidence interval of the CIF, or rather, for reasons of normality, that of its logarithm, is obtained by using the usual formula $\ln(\text{CIF}) \pm z_{0.025} \sqrt{\text{Var}(\ln(\text{CIF}))}$, the estimation of the CIF variance logarithm being

$$\text{Var}(\ln(\text{CIF})) = \frac{m_1}{nve_1^2} + \frac{m_2}{nve_2^2},$$

$m_1$ and $m_2$ being the number of events considered, $nve_1$ and $nve_2$ being the numbers of vehicles exposed to the risk considered (Breslow & Day 1987).

Then we use the ratio between the number of injury vehicles (as described above) and the number of vehicles involved in all crashes. Note that this ratio is relevant to estimate the severity if there is no difference between the two IRs according to the type of hard shoulder.

Finally we use a logistic regression model to take into account some potentially confounding factors available at the site of each accident (such as weather conditions, horizontal and longitudinal profiles, etc.). The factor to be explained is the severity, or more precisely the probability of occurrence of at least one casualty in a damaged vehicle (or inside another vehicle hit after the first impact). With k covariables, the logistic model takes the following form:

$$\Pr(\text{at least one casualty in damaged vehicle}) = \exp(\sum_{k=0}^{K} \beta_k x_k) \left/ \left(1 + \exp(\sum_{k=0}^{K} \beta_k x_k)\right)\right.$$  

This is a multiplicative model, which takes the influence of k covariables $x_k$ into account. Its parameters are classically calculated using maximum likelihood estimations. The comparison of two models is done by testing the ratio of likelihood, provided that these models are nested (McCullagh & Nelder 1989). The exponential of a $\beta_k$ is interpreted as the Odds-Ratio (OR) associated with $x_k$ in comparison to the reference level. As this is an exposed-unexposed study, $\beta_0$ is interpreted as a function of the basic risk $R_0$ and the relative risk (RR) can be estimated from the OR by using the expression deduced directly from their respective definitions: $RR = OR / (1 + R_0(OR - 1))$, with a specific confidence interval calculation (Martin et al. 1997a). Another factor, overturn, can be viewed as an intermediate factor and is examined separately according to the type of vehicle.
Results

At least one vehicle runs off the roadway onto the hard shoulder for 32% of crashes on 2 lane motorways and 27% on 3 lane motorways. As shown in Figure 2, 93.2% of the 9,934 crashes where at least one vehicle runs off the roadway onto the right shoulder as a first event are involved in a single vehicle crash. The choice to use the vehicle rather than the crash as a statistical unit will therefore not lead to a noticeable difference in the result. On the whole, 10,164 vehicles run off the roadway onto the right shoulder, i.e. 18.8 % of the vehicles involved in crashes.

![Figure 2: Crash type and number of vehicles involved](image)

Table 1 shows the Incidence Rates of vehicles running off the roadway onto the hard shoulder according to whether hard shoulder is equipped with barriers or not, as well as the IR of "injury vehicles".

<table>
<thead>
<tr>
<th>Equipment of hard shoulders</th>
<th>With barriers</th>
<th>Without barriers</th>
<th>CIF</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR_T (total Incidence Rate)</td>
<td>8.93</td>
<td>8.61</td>
<td>1.04</td>
<td>(0.98-1.09)</td>
</tr>
<tr>
<td>IR_C (Casualty Incidence Rate)</td>
<td>0.95</td>
<td>1.86</td>
<td>0.51</td>
<td>(0.45-0.58)</td>
</tr>
</tbody>
</table>

With \[ IR_T = \frac{\text{number of crashed vehicles}}{nve} \times 10^8 \]
\[ IR_C = \frac{\text{number of crashed vehicles with at least one casualty}}{nve} \times 10^8 \]
\[ nve = \sum_{\text{sections}} \left( \text{daily mean traffic} \times \text{number of observation days} \times \text{observed length} \right) \]

There is no significant difference between the IR concerning the total number of crashed vehicles (addition of injury and property damage only vehicles). The presence of the barriers does not seem to have an influence on the occurrence of accidents. On the other hand, the IR for injury vehicles is significantly higher when there is no barriers on hard shoulders. The results are the same if we separately calculate these IR according to the number of lanes of the motorways (2x2 vs. 2x3 lanes).
Considering that, we can use the percentage of vehicles in which there is at least one casualty to the total number of crashed vehicles as the severity criterion. Table 2 shows the different values of this criterion according to the type of hard shoulder, as well as to other types of accidents.

### Table 2 - Severity in vehicles according to type of 1st impact

<table>
<thead>
<tr>
<th>Scene of first impact</th>
<th>% with casualties</th>
<th>% with fatalities</th>
<th>Number of vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of need</td>
<td>10.4</td>
<td>0.6</td>
<td>7,792</td>
</tr>
<tr>
<td>Ends</td>
<td>17.8</td>
<td>2.2</td>
<td>135</td>
</tr>
<tr>
<td>Without barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-side profile: flat</td>
<td>22.3</td>
<td>2.7</td>
<td>408</td>
</tr>
<tr>
<td>Above road level</td>
<td>23.4</td>
<td>1.9</td>
<td>1,169</td>
</tr>
<tr>
<td>Below road level</td>
<td>19.3</td>
<td>1.5</td>
<td>616</td>
</tr>
<tr>
<td>With &amp; without</td>
<td>13.1</td>
<td>0.9</td>
<td>10,164</td>
</tr>
<tr>
<td>Central reservation</td>
<td>10.8</td>
<td>0.7</td>
<td>11,246</td>
</tr>
<tr>
<td>Roadway</td>
<td>10.6</td>
<td>0.9</td>
<td>32,637</td>
</tr>
</tbody>
</table>

The severity is higher (13.1%) when the first impact occurs on hard shoulder compared to the central reservation or the roadway. But this global severity value includes very different phenomena: When we consider impacts on right shoulders equipped with barriers, the severity observed is very close to that of other scenes of first impact, except for the ends of barriers. It is about twice as high when there is no barrier. This is also true when we consider the percentage of first impacts with fatalities.

As described above, the majority (90%) of safety barriers are W-beam guardrails (containment level N2 in European denomination), but about 8% are New Jersey profile concrete barriers. The value of 10.4% of the severity on length of need barriers actually includes two different values: 9.8% for the metal guardrails vs. 16.9% for the concrete barriers. These estimations are coherent with a previous study focusing on this comparison for run off the roadway onto the central reservation (Martin et al. 1997b).

Some factors are linked both to the severity and to the equipment of the hard shoulder, hence constituting potential confounding factors such as the motorway profile (up slope or down slope, curve radius of bends) and the number of lanes. All these factors, as well as the number of vehicles involved in the same crash, and the type of vehicle (cars or trucks and vans), are put into a logistic regression for fitting purpose. Table 3 shows Relative Risks associated with the different factors. Figure 1 indicates the reference level for each one and RR are significantly different from 1 when their confidence interval does not include the value 1.
Table 3 - Severity in vehicles according to type of 1st impact fitted by logistic regression: Parameter estimates, Relative Risks and 95% Confidence Intervals

<table>
<thead>
<tr>
<th>Factor*</th>
<th>( \beta )</th>
<th>RR</th>
<th>95% C.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>right shoulder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>length of need ends</td>
<td>0.58</td>
<td>1.68</td>
<td>1.12-2.53</td>
</tr>
<tr>
<td>without barriers (right-side profile)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flat</td>
<td>1.01</td>
<td>2.41</td>
<td>1.96-2.98</td>
</tr>
<tr>
<td>above road level</td>
<td>1.07</td>
<td>2.53</td>
<td>2.21-2.89</td>
</tr>
<tr>
<td>below road level</td>
<td>0.76</td>
<td>1.96</td>
<td>1.62-2.37</td>
</tr>
<tr>
<td>vertical grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>flat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>climb</td>
<td>-0.07</td>
<td>0.93</td>
<td>0.82-1.06</td>
</tr>
<tr>
<td>downhill</td>
<td>-0.06</td>
<td>0.94</td>
<td>0.82-1.09</td>
</tr>
<tr>
<td>horizontal curvature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&gt;5000m</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2000&lt;R&lt;5000</td>
<td>0.15</td>
<td>1.15</td>
<td>1.01-1.31</td>
</tr>
<tr>
<td>1000&lt;R&lt;2000</td>
<td>0.42</td>
<td>1.46</td>
<td>1.23-1.72</td>
</tr>
<tr>
<td>R&lt;1000m</td>
<td>0.40</td>
<td>1.44</td>
<td>1.20-1.72</td>
</tr>
<tr>
<td>Number of lanes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.09</td>
<td>0.92</td>
<td>0.82-1.03</td>
</tr>
<tr>
<td>Vehicle type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cars</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Trucks and vans</td>
<td>0.38</td>
<td>1.41</td>
<td>1.21-1.63</td>
</tr>
<tr>
<td>number of vehicles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.73</td>
<td>1.91</td>
<td>1.60-2.30</td>
</tr>
<tr>
<td>3</td>
<td>1.23</td>
<td>2.86</td>
<td>2.27-3.60</td>
</tr>
<tr>
<td>4 and more</td>
<td>2.28</td>
<td>5.72</td>
<td>4.64-7.04</td>
</tr>
</tbody>
</table>

First of all, the severity of impacts is twice as high or more when there is no guardrail, compared to length of need guardrails. It is also more severe on ends of guardrails. These results, expressed in Relative Risks adjusted on the other factors included in the regression, confirm the rough results of Table 2. Among the potentially confounding factors, vertical grade and number of lanes have no significant effect on severity. On the other hand, impacts are more severe for bends (which corresponds to different crash configurations) and for trucks and vans (regrouped because of close severity values). As expected, the severity increases with the number of vehicles involved, but this fact is also taken into account by means of the severity indicator chosen, as previously explained. We note that 4.4% of vehicles hitting a guardrail cause or suffer a second impact with another vehicle, while this is extremely rare when there is no barrier.

Another factor worth studying, as it is highly associated with the severity of crashes, is the overturn. As it can be considered as an intermediate factor between the severity and the presence or not of a barrier, it is better not to include it in the regression but to examine it separately.
Table 4 - Overturns after 1st impact on right-side profile of scene of 1st impact cars trucks & vans

<table>
<thead>
<tr>
<th>scene of 1st impact</th>
<th>% overturn</th>
<th>Number</th>
<th>% overturn</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>with guardrails</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>length of need ends</td>
<td>5.7%</td>
<td>6,844</td>
<td>22.9%</td>
<td>846</td>
</tr>
<tr>
<td>without guardrails</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>right-side profile: flat</td>
<td>16.8%</td>
<td>333</td>
<td>20.3%</td>
<td>69</td>
</tr>
<tr>
<td>above road level</td>
<td>24.3%</td>
<td>1,002</td>
<td>24.2%</td>
<td>165</td>
</tr>
<tr>
<td>below road level</td>
<td>18.6%</td>
<td>516</td>
<td>26.3%</td>
<td>95</td>
</tr>
<tr>
<td>total</td>
<td>9.0%</td>
<td>8,807</td>
<td>22.9%</td>
<td>1,198</td>
</tr>
</tbody>
</table>

Table 4 shows that the number of cars suffering an overturn is minimum for length of need barriers, and much higher for hard shoulders without guardrails. This clear difference is not true for trucks and for vans as well, with a mean proportion of nearly 23% of overturns. Regarding motorcycles, a very low number of crashes involving two-wheel vehicles has been recorded, i.e. 328 to be compared to nearly 54,000 four-wheel vehicles. Among them, only 5% (N=19) motorcycles ran off the roadway onto the hard shoulder (causing 14 casualties) which is a much lower proportion than for the four-wheel vehicles (25%). This low number does not allow any conclusion to be reached about the severity of motorcyclists involved in crashes compared to the equipment of hard shoulders.

Discussion

Compared to our previous study concerning the years 1985 to 1995 (Martin et al. 1997a), the rate of equipped hard shoulders has gone up from 55% on average to 78%. Nevertheless, the number of run off the roadway onto hard shoulder without barriers is big enough to see a significant difference of severity, compared to hard shoulders with barriers, with Relative Risks of the same order. This is true whatever severity criterion is used (rough RR with casualties or fatalities, adjusted RR or Incidence Rates). This result is strengthened by the fact that installing guardrails along the edge of the road does not seem to affect the probability of accident occurrence (nor accident recording), as shown in Table 1. Our estimations are in accordance with the conclusions of Schoon (Schoon 1999) and with the meta-analysis carried out by Elvik (Elvik 1995), as he found that guardrails reduce the chance of sustaining a personal injury by about 50%.

Concerning the ends of the barriers, the risk of injury is significantly higher than for the "normal" part of the barrier, as shown in our previous study. But it is slightly lower than without barriers, while this was previously the contrary. One part of the explanation could be that most dangerous barrier ends have been removed or modified, but our data lacks precision to confirm this hypothesis. Anyway, more systematic equipment of hard shoulders will automatically reduce the number of ends of barriers and hence improve safety (Cornell 1996), (Hunter et al. 1993).

The possible increase of second impacts with other vehicles because of the presence of barriers has been established, but concerns a rather low percentage of crashes. This is why, even when we take this phenomenon into account, it does not significantly affect the estimated severity.
If we consider the problem of the overturns as a whole, their number has been decreasing compared to our previous observations, which could be attributed to some improvement in the vehicles. Anyway, what makes the difference between the percentages of overturns whether there is a guardrail or not is the behavior of cars rather than trucks and vans: only 5.7% of overturns are observed, which carries more weight as it concerns about 68% of vehicles involved in crashes. This confirms that guardrails usually set up along the roadside are quite well optimized for French (and European) cars. However, the evolution of European cars, notably the average weight increase, will result in an evolution of guardrails too in a near future (with a higher containment level) while in the US, evolution of roadside features to accommodate vans, pickup trucks and 4-wheel drive vehicles is a current issue (Bligh & Mak 1999).

In Ross (Ross 1995), a forgiving roadside is basically "one free of obstacles that could cause serious injuries to occupants of an errant vehicle. To the extent possible, a relatively flat, unobstructed roadside area is desirable, and when the conditions cannot be provided, hazardous features in the recovery area should be made breakaway or shielded with an appropriate barrier". This study shows that, even when the terrain is flat, i.e. with a slight difference of level between the roadway and the roadside, the average severity of crashes is higher when there is no barrier. This is due to a higher number of overturns, but not only as it is still true when we remove overturn cases. To be really forgiving, roadsides should be very well built in accordance with vehicle characteristics, with no culvert for the drainage system and a specific surface aiming to smoothly slow down any errant vehicle. Furthermore, the basic condition "free of obstacle" is very difficult to respect because roadways cannot be as wide as desired due to costs and growing urbanizing.

On the other hand, safety barriers are in very good conditions to work correctly on motorways, as impact angles are mostly low. This is probably why the results are so favorable, and encourage us to advise systematic equipment of hard shoulders with safety barriers. This advice supposes that the number of motorcyclists is low (as shown in our previous study), and cannot be generalized without cautions for other types of roads where conditions of impact are totally different. Starting from our estimations, motorway managers should be able to carry out a cost-benefit analysis taking the motorway user safety into account, but also motorway workers safety, maintenance and traffic considerations.

Conclusion

Systematic equipment of highway hard shoulders appears to be beneficial as a whole within the infrastructure and European traffic conditions, with a better control of run-off the road consequences. Moreover, the subsequent suppression of most of the ends of guardrails should also increase safety.

Acknowledgements

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ACCIDENT DETECTION THROUGH DIGITAL VIDEO ANALYSIS
AS AN OPTION TO INCREASE TUNNEL SAFETY

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Introduction

The safe operation of tunnels requires a fast and reliable incident detection. Only precise information about the place, type and extent of the incident allows for a selective launch of measures, e.g. regulation of the ventilation system for smoke control in case of fire, or the halting of traffic outside and inside the tunnel following an accident.

At present, different types of detectors are deployed in tunnels to monitor the traffic area. The collection of traffic data is generally done through local measurement devices such as induction loops or overhead infrared sensors. Fire incidents are detected through fire detecting cables, fog sensors, or the removal of fire extinguishers from emergency stations. When video equipment is installed, these detectors are linked with cameras, so that an image from the incident spot is switched on in the permanently occupied control rooms.

However, the fire events over the past years have shown that, often, fires were only detected by the optic sensors (fog sensors).

Using the appropriate evaluation logarithms, meanwhile available computing capacities allow for an analysis of video data in real time and, at the same time, to automatically detect the type and extent of the incidents as well as their spatial and temporal causes.

Apart from traffic data such as
- traffic flow
- traffic density
- speed,

the following incidents can be detected automatically on the video image:
- formation of fire and smoke
- stopped vehicles
- use of hard shoulders resp. emergency bays
- ghost drivers
- persons resp. objects on the road
- changes in illumination.

The online analysis of the video data then makes the direct and selective control of operating functions possible immediately following the incident occurrence. A further advantage of digital video analysis lies in the storage of recorded data, which can serve in the subsequent reconstruction of incidents.

In the chapter below, the basics, procedures and input potentials of digital video analysis are listed.
Basics of the Digital Video Analysis

Images must be available in digital form for further processing. For this, it is necessary that image F can be described mathematically with an image function \( f(x,y) \). Since an image can be seen as a continuous distribution of intensities, function \( f(x,y) \) describes the single intensities of the pixels. In case of colour images, this intensity is divided into several colour channels (multi-channel pictures). Generally, these are the colours red (R), green (G), and blue (B), so that the function \( f(x,y) \) turns into a vector function as follows [Stöpp 1998]:

\[
\begin{align*}
\mathbf{f}(x,y) &= \begin{pmatrix} f_R(x,y) \\ f_G(x,y) \\ f_B(x,y) \end{pmatrix}
\end{align*}
\]

The brightness proportion of the video signal is described as luminance. Out of the three signals red, green and blue (RGB) of the camera, a weighted mean value is calculated, which takes into consideration the properties of the human eye. Thus the colour green is weighted with 59%, red with 30% and blue with 11%. The luminance corresponds to the grey value \( f(x,y) \) in case of grey tone pictures.

In order to save expenses, the operations of digital image processing are predominantly carried out on the basis of grey tone pictures. In this case, it is recommended to preselect a single-channel grey tone picture as the image source.

In order for images to be changed and further processed on computers, the image functions must be brought into a suitable computerized respectively numeric form. This process is called digitalization. This includes “screening” and “quantization”. The resolution and the number of quantization steps are a measure for the maximum image definition.

During the process of screening, the domain \((x,y)\) is divided into \(m\)- resp. \(n\)-intervals \((x_j, y_k)\) for \(x\) and \(y\) direction respectively. The result is a \(m\times n\)-matrix of values \(f(x_j, y_k)\), of which each represents a pixel (fig. 1). The range of values of the image coordinates then extends from 0 to \((m-1)\) in \(x\)-direction, respectively from 0 to \((n-1)\) in \(y\)-direction.

![Fig.1: Screening (Brake 2001)](image-url)
The assignment of grey values following the screening process is called “quantization”. For technical reasons, it is sensible to select a two-to-the-power of “x” number. Generally, an 8-bit structure is used, so that $2^8 = 256$ grey tones. These levels then range from 0 (= black) to 255 (= white).

If, instead of a single image, a screen sequence is looked at, the domain of the image function must be extended by the dimension of time (fig. 2). Thus an expression of form $f_t(x,y)$ follows.

Screen sequences can be analyzed on the basis of grey zone changes with respect to movement. Depending on which image these changes refer to, procedures are distinguished by screen sequence and reference image.

$$d_F(x,y) = f_{t-1}(x,y) - f_t(x,y)$$

The disadvantage of this procedure is that areas, which cover the object in the current and the previous image, are identified as moved regions. As can be seen from fig. 3, this causes double edges to appear, whose distance among themselves depends on the speed of the object. A further disadvantage lies in the fact that vehicles at a standstill do not generate a difference image. The advantage of this procedure is that gradual changes in the background image do not have a negative effect on the identification of the object through the constant update of the comparison image.
The reference image procedure is the method, with which a predetermined background image serves as comparison image. When using video techniques for traffic surveillance, the reference image shows the empty road (fig. 4).

The difference image function \(d_R(x,y)\) with fixed reference image is:

\[
d_R(x,y) = f_0(x,y) - f_i(x,y)
\]

The reference image must be updated constantly, so that an allowance can be made for slowly occurring changes in the background. Mostly, a good adjustment can already be obtained by merely updating single pixels within a particular interval. Only on completion of a certain cycle, the entire background is updated. If the lighting conditions inside the tunnel are constant, the reference image need not be adjusted.

The detection of moved areas can be made more difficult through signal noise. In order to minimize wrong decisions, threshold values should be defined to ensure reliable detection. If too low a threshold value is selected, the noise from the camera only could be interpreted as movement. In contrast, when the threshold value is too high, actual movements may not be recognized at all (fig. 5). One way of minimizing wrong decisions is by using a threshold value that depends on the grey zone level of the area surrounding the pixel in question, which is thus not a constant value for the entire image.
Procedures of the Digital Video Analysis

Tripwire Systems

Tripwire systems are based on virtual detectors with different properties, which can be placed on the monitor arbitrarily. For this purpose, line, traverses and area detectors are used; compared to a full-screen analysis, this method reduces the computing time considerably. As the vehicle crosses the detector, changes in the grey zone are recorded within the respective detection section. By specifying the threshold limit for the detection sensibility as well as for the video signal noise, errors through shadow casting of neighbouring objects can be eliminated. This is particularly important to avoid multiple detection when using several, closely adjoining detectors. For this reason, the properties of each detector must be adjustable separately. Classification of the vehicles is done according to vehicle height, width or length, depending on the camera angle. The vehicle speeds, for example, can be determined by combining two successively arranged detectors. Fig. 6 shows the technique for digital video analysis (isac-DVA) developed by the Institute for Road Engineering Aachen, which is based on a tripwire system.
Tracking Systems

Tracking systems are based on the process of tracking pixel changes between the sequential frames of a video image. By combining pixel groups into objects – so-called “blobs”, which are made up of encasing geometrical figures (generally rectangles) – vehicles can be detected. A classification of the vehicles can, for example, be made through stipulation of the wing area of the blobs or their edge lengths. In order to differentiate vehicles that are moving in a row from the system, definitions of minimum or maximum vehicle lengths, or minimum distances respectively time intervals between the vehicles, are sensible. The speed of the vehicles is calculated from the displacement of the objects between the frames. By using a Kalman-filter, the subsequent blobs can be inferred from the current blobs. Accordingly, when combining with the Hough-transformation at interrupted lines, the progressive sequence of objects can be deduced, even when they are partly covered (Jähne, 1997). The advantage of this method consists in that as many as desired objects can be traced simultaneously, even when a certain occlusion of single objects occurs.

The tracking system integrated in the *isac*-DVA 2.0 software developed by the Institute for Road Engineering Aachen is shown in fig. 7. Vehicles at standstill are framed with orange colour when detected, vehicles travelling in line of sight with green colour, and vehicles driving in opposite direction in red. Persons on the roadway are marked in yellow.
Fire Detection

When vehicles catch fire, a plume develops first, in which the hot gases mount towards the tunnel ceiling. Depending on the type of fire, the smoke could be black or white. Subsequently, the smoke spreads along the tunnel ceiling and cooling processes take place, which can lead to an instant descending of the smoke to the ground.

The automatic smoke detection is based on a continuous examination of the image for especially light or dark interrelated image zones. For this purpose, the area to be examined is first divided into square regions by a raster (fig. 8). In each raster element, a representative pixel is cyclically – e.g. each second – examined for white and black smoke. Contrary to the movement analysis procedure, not the grey value differences, but the absolute grey values (luminance) count here.

From experience, within a grey value range of 0 to 255, the threshold for white smoke lies close to the upper border of the grey tone spectrum. In case of black smoke, detection is made at a low grey value, depending on the lighting situation in the tunnel. Since the image of an incident-free tunnel – e.g. in areas in which there are lamps – already possesses very bright zones, these areas must be excepted for the detection of white smoke.
Accident detection through digital video analysis as an option to increase tunnel safety
by Dipl.-Ing. Georg Mayer, Institut für Straßenwesen (isac), RWTH Aachen

The alarm is set off by the following factors

- the number of detected pixels
- the number of interrelated detected pixels

![Image](image-url)

**Fig. 8: Especially light (orange) and dark (red) areas (isac-DVA 2.0)**

**Identification of Dangerous Goods Transport**

If, in case of fire, transporters with dangerous goods are involved, it is most important for the task force to have information about these goods, so that the fire can be fought effectively. This requires a – if possible, automatic – logging of such transport. Dangerous goods transports by road are marked with an orange-coloured, 40x30 cm sized sign giving the dangerous goods number as well as the material number (UN-number). If a vehicle contains several different dangerous goods, for example in several tanks or in the form of bulk, the warning signs in front and at the back are blank; the dangerous goods are then marked on the side of the tanks or on the bulk itself with the respective identification numbers.

Owing to the usual frame frequencies (frames per second) and resolutions (in PAL-standard), an automatic identification of the danger and material identification numbers is practically impossible from the way the cameras are being positioned to monitor the traffic (see fig. 9).
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Fig. 9: Unrecognizable warning signs under normal conditions

In order to make identification of the signs possible, the camera angle must be selected such that the expected position of the signs is zoomed in. With a digital colour filter, the single images are checked for areas with an orange colour. The regions thus found are subsequently examined for existing lettering with the text recognition function. Fig. 10 shows the different situation of moving warning signs before and after the orange filtering process. The effect of the digital colour filter and the readability of the lettering, which is necessary for an automatic text recognition, can be clearly seen.

Fig. 10: Warning sign before and after the orange filtering process (isac-DVA 2.0)

In order to record dangerous goods transports, the identification of warning signs at the beginning and at the end of a tunnel is sufficient. The exact positioning in the tunnel can then be done through usual tracking procedures.

The Video System Setup for Tunnels

Requirements for the Installation and Alignment of a Video Camera

In order to ensure positive detection, it is important that no vibrations or commotions caused by wind forces occur during the installation of the video camera. Furthermore, the camera should be positioned as high as possible above the lane, in order to avoid or to minimize as much as possible interactive occlusion of vehicles and perspective distortion. Basically, the following rule applies: the higher the tilt angle of the camera selected, the more reliable the
detection of single vehicles. In contrast, small tilt angles render the differentiation between single vehicles more difficult; on the other hand, they display a larger detection area. As a rule, mounting the camera in tunnels in the crown above the middle of the lane, is the best solution (INTEC, 1999). Suggestions for the installation of video cameras are given in table 1.

<table>
<thead>
<tr>
<th>Number of Lanes</th>
<th>Centre of Lane</th>
<th>left outside</th>
<th>right outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 m</td>
<td>8 m</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>7 m</td>
<td>10 m</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>8 m</td>
<td>18 m</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>12 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 1: Suggestions for the installation of video cameras (INTEC, 1999)

**Image Processing Systems**

In video technology, two basic techniques of image processing must be differentiated:

- Analysis of image in the camera (pre-analysis)
- Image analysis of the video signal (post-analysis)

The principle of preliminary image processing is shown in fig. 11. Apart from the image recording, the image analysis takes place in the camera with the aid of appropriate hardware. The positioning and the properties of the detectors can be entered via an operating computer. This computer receives and also processes the traffic data generated by the camera unit.

![Image recording](image1.png)

![Control](image2.png)

![Traffic data](image3.png)

![Analysis](image4.png)

**Fig. 11: Principle of the preliminary image analysis (Brake 2001)**
Accident detection through digital video analysis as an option to increase tunnel safety
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In contrast, for the post-analysis of images (fig. 12), the entire video signal is first transferred
to the computer, either through a storage medium, or directly. The analysis of image data is
then done through computer software.

![Image of image post-analysis process]

**Fig. 12: Principle of the image post-analysis**

### Video Analysis System

Suggestions for the setup of a video analysis system for the entry of traffic data and automatic
incident detection in tunnels are shown in fig. 13.

![Diagram showing components and setup of a video monitoring system for tunnels]

**Fig. 13: Components and setup of a video monitoring system for tunnels (Brake 2001)**

With the aid of cameras at the tunnel portals, the entries and exits of dangerous goods
transports are registered. As opposed to those cameras inside the tunnel, they are directed
towards the expected position of the warning signs and, for this reason, cannot register any
other traffic data.

All cameras mounted in tunnels serve to record traffic data and to detect incidents. If a
classification of vehicles is to take place, this is done once only at the first camera location (at
the entrance of the tunnel). In a preliminary stage, processing of image data is done in the
cameras. Data transmission is then done via hubs, through which the central computer
receives already analysed traffic data respectively incident notifications.

The number of cameras that can be connected to one hub depends on its computing capacities.
Since the amount of data sent by the hubs is relatively small compared to the total of recorded
image data, any amount of users can be connected to the central computer. This system setup
allows for the input of one and the same system for tunnels of different lengths.
The central computer records the supplied data, analyses them online and decides automatically, which measures should be taken. If, for example, one camera has recognized the occupancy of the marginal strip respectively a breakdown bay, it supplies data with respect to the type and place of the incident to the central computer. The central computer can then initiate directly further suitable measures, as well as transmit visual information about the incident situation to a permanently occupied control room.

**Conclusion**

Digital video analysis allows for the integration of several types of detection within one system and can therefore be applied flexibly and universally. Consequently, apart from the pure collection of data, the entry of dangerous goods transports well as fires can be detected. Given a pertinent configuration of the cameras, a complete observation of the traffic area is possible. Since the analysis of data is done in real time, measures can be initiated immediately following the occurrence of an incident. Additionally, an on-the-spot video image is available at all times. Furthermore, owing to the camera arrangement in the ceiling area, no drawn-out interventions are necessary in case of maintenance or repair jobs to the road surface.

**Literature**


**Software**

Brake, Martin und Georg Mayer *isac-DVA 2.0*, Softwareumgebung zur digitalen Videoanalyse, Institut für Straßenwesen, Aachen.
Motorway Control Systems at highly-stressed Motorways in a Metropolitan Area

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1 Introduction

Motorway lane and network control systems are modern tools of an efficient traffic management. Especially the motorway network in metropolitan Hamburg is heavily stretched with an Average Daily Traffic (ADT) of 23,000 vehicles per lane and a high percentage of heavy vehicles. The forecasts expect an increase of the ADT of about 20% till the year 2020. Traffic management tools may help as an appropriate measure to get better overall traffic safety and flow conditions on the motorways.

The basic structure of the Hamburg motorway network is the motorway A1 and A7. The two motorways belong to the most important ones in Germany. The A1 connects the south-west of Germany via Cologne to the north, and the A7 represents the connection between the south of Germany via Hanover. Further motorways – A23, A24 and A25 - open the region round the Hamburg area (Figure 1). As the motorway A24 connects the Berlin area with Hamburg it owns a higher importance than the others. Moreover the Hamburg motorway network is completed by four short motorway sections. One of the very well-know sections of the motorway A7 is the Elbe tunnel. The surrounding federal states (the so-called Länder) are Lower-Saxony in the south and the west and Schleswig-Holstein in the north of Hamburg metropolitan area. The planning of a motorway control system is independent of the border of the Länder. The traffic problems are overlapping therefore it was obvious that the planning of a motorway control system is only possible and workable by a co-operation of the three Länder: Hamburg, Lower-Saxony and Schleswig-Holstein. The participating Länder have charged a consultant with the preparation of traffic and accident data, the analysis of the situation and the development of ITS proposals [S.S.P., 2000].

The planning and decision making procedure has to be clear and comprehensible to be supported by the political decision-makers and financially by the German Ministry of Transport. In Germany the Länder are responsible for the motorways under the supervision of the Federal Ministry of Transport. The method of the planning procedure is divided into four main steps. In the first step critical sections were defined by taking into account the situation of traffic, accidents and incidents and the geometry of the cross-section. This analysis represents the basis for finding critical sections which are promising for additional traffic engi-
engineered measures. The sample was conducted by the view of the fact that other motorway control system are planned or are under construction, by the view of the operation frequency and the instability of the traffic flow. In the following step the measures were ordered temporarily by the urgency and an analysis of the benefit-cost. In the last step the sharing out of investment cost between the participating German federal states were carried out.

The accident situation of all Hamburg motorways were analysed by the accident rate accident density to get an idea where it will be useful to concentrate the analysis of the accident situation and to implement traffic engineering measures. The accident rate and density was evaluated for accidents with fatalities and casualties in 1999. The motorways were graded by the value of the rate or density. Both criteria have pointed to the most critical motorways of the network. It was foreseeable that the efforts would concentrate on the A255, the A1 and the A7. The total number of accidents of the A1 and A7 is much higher than on the others with a clear improvement potential existing there [FHH, 2000]. In the following the report focuses and concentrates on the motorway A1. The situation and analysis of the motorway A7 is nearly the same.

Figure 1: Hamburg Motorway Network [according: BMV, 1996]
2 Traffic Flow

Aim of a motorway control system is on one side the improvement of the accident situation but on the other the improvement of the traffic situation and conditions. The traffic situation was described by the traffic flow. The traffic flow was evaluated by the average daily traffic (ADT) not only in 1999 but also in 2010 (Figure 2). The forecast is necessary to optimise the implementation with regard to optimal benefit. The ADT will increase regularly by 15% to 20%. An ADT per lane of 20,000 is a critical value and corresponds on German motorways an insufficient D-level of service. The evaluated ADT represents a value of all days per year so e.g. an ADT of Fridays is distinctly higher. Two sections with an ADT in a high range are conspicuous: most of the Hamburg area and the south of it.

Figure 2: ADT in 1999 and 2000 of Motorway A1

3 Traffic Safety

The accident situation was analysed more detailed in two steps. In the first step the accident rate for fatalities and casualties (AFC) separated into sections and differentiated between the driving directions northbound and southbound was analysed (Figure 3). A rate of 0.13 AFC per 10E6 veh-km is in accordance with the German average. In the southbound the sections in the vicinity of the interchanges 31 and 35 [BMV, 2001] are striking in the Hamburg area and out of the Hamburg area the access point 27 seems to be accident-prone. In the counter-direction the same interchange 35 is over the average and in the running to the
Hamburg area the interchange 43 is conspicuous. In general the sections out of the Hamburg area are not noticeable.

**Figure 3:** Accident Rate in 1999 of Motorway A1

**Figure 4:** Number of Causes of Accidents in 1999 of Motorway A1

In the second step the accident analysis was focused only on the Hamburg area to get detailed information for every locality. The accident evaluation presents on one side the total
number of accident in each short motorway sections on the other side it gives an information of the main accident causes speeding, distance keeping, overtaking, other driving mistakes and other causes (Figure 4). It is very striking that in direct area of an interchange or access point the number of accidents is much higher than on free sections. Besides insufficient distance or mistakes by overtaking cause the most accidents. This situation is as well in the northbound as in the southbound.

4 Critical Sections

On the basis of the carried out investigations critical sections were localised (Figure 5). The critical sections were differed by the extent of dislocation. For the optimisation of the implementation it is necessary to take into account the temporary development of the critical sections. The situation is described by the alteration for the year 2005 and 2010. Two main critical sections in the north-west and in the east of Hamburg can be detected in 2005. In the following five years the range of the critical sections increases distinctly at the critical interchanges and sections. The critical section round the Elbe tunnel will disappear by opening the 4th tunnel tube.

![Figure 5: Critical Sections in 2005 and 2010](image-url)
5 Implementation of ITS

On the basis of the carried out analysis the implementation of new ITS was deducted (Figure 6). In January of 2001 the motorway control system in the running of the A7 was taken in operation. The essential new ITS measures are an motorway control system for the motorways A1 and A24. The implementation will be carried out in two steps. In addition a controlling of the interchanges will be implemented. The implementation of ramp metering is under increasing discussion so appropriate access points for the implementation of ramp metering were proposed. A further ITS measure will be implemented by a network control to have alternative routes in the northern part of Germany. The metropolitan area of Hamburg will mark the southern part of a network loop.

Figure 6: Existing and future ITS Projects of the Hamburg area
6 Benefit-Cost-Ratio

The measures were verified by the benefit and cost. The benefit was defined by the alteration of the accident costs and the alteration of time costs. The cost rates were assumed on the basis of a German guideline. But it is difficult to make appropriate assumptions of the alteration of accidents and incidents. The alteration of accidents bases on a research project initiated by the Federal Ministry of Transport in a range of – 20% to – 30% [BMV, 2000]. In contrary the alteration of incidents were assumed by having made experiences of the charged consultants. The benefit-cost-ratio is a range between 1 to 3.0 to 3.9 for each ITS-measure.

7 Outlook

Most of the ITS-projects were become part of the announcement for Federal Telematic Program. This project is embedded in the VIKING- program of the European community. VIKING is a co-operation between the states of the northern part of Europe. The implementation will be supported by VIKING, too.

References


Abstract
About ten years after the "new wave" of roundabouts has flooded Slovenia, at the moment, when there are twenty-seven roundabouts installed all over the country, when further increase of their number is foreseen and when the proposal of Slovenian regulation for designing of roundabouts is in its stage of ratification, there is an opportunity for a general review of process concerning roundabouts in the Republic of Slovenia.
In the paper the Slovenian experiences about roundabouts in build up areas are presented.

Introduction
During past almost ten years in the Republic of Slovenia the roundabouts have become more and more interesting for both designers and investors.
Our deeper interest for roundabouts started in last decade and until that time, in Slovenia we practically had no significant experiences with roundabouts and their advantages in road traffic.
When Slovenia became an independent country in the beginning of 90s, the need for establishing new legislation for the field of road construction and road traffic appeared.
Among many other measures, the Slovenian Traffic Ministry founded the Group for Roundabouts, and its main task was preparation of guidelines for planning and constructing of roundabouts. The Group has finished its work in May 1999 and the final version of guidelines [1] is in the legal procedure right now. Today we have 27 roundabouts and some more under construction.

The history
Considering the chronic lack of professional literature on roundabouts in the first stage, the excess of professional literature, manuals and guidelines of other countries in the second stage, the lack of our own guidelines for roundabouts in the third stage and the number as well as the consequences of traffic accidents, we can affirm with complete responsibility that both, the designers and the contractors, did their work professionally, with a high measure of quality.
The process of introducing roundabouts into the Republic of Slovenia had a number of participants, who, although a little later, also joined in. Without their co-operation, the process would be much less successful. These are the road-police, media, driving schools, etc.
Especially media, unlike driving schools, are the major means of providing information to the largest number of users - to PCU drivers, pedestrians, as well as cyclists.
After initial enthusiasm at introducing the first roundabouts into Slovenia; in cities Ljubljana (Picture 1), Maribor, Koper, Velenje (Picture 2), Gorica …, first questions concerning the justification of their installation and actual traffic safety, which they provide, appeared. Considering that roundabouts in Slovenia where at the time a novelty (with exception of some rare earlier examples), such caution is completely understandable.
There was namely no assurance that roundabouts in Slovenia would prove themselves appropriate, like they did abroad. With regard to the fact that ten years ago roundabouts were practically an innovation, there were some hindrances and expectations of effects, opposite to those, which roundabouts were actually designed for: The lack of our own guidelines forced the designers to choose among foreign guidelines. Thus, the choice of a certain guideline depended on designer’s subjective estimation and on literature, which was attainable at that time. This caused a partial disunity at designing the first few roundabouts in Slovenia. In other words, every roundabout was designed according to different guidelines. This is objectively understandable; as, until recently, there was no official or individual person, who would with his experience and theoretical knowledge of roundabouts be able to decide with certainty, which of the foreign guidelines should be taken as standard in Slovenia.
However, the literal and direct application of foreign guidelines in Slovenia would be unacceptable and nonsensical, it would namely not be a result of actual traffic circumstances, and would at most cause unsuitable (if not negative) effects. In spite of the facts, which have already been mentioned in the text above, roundabouts turned out well, even right after introducing them into Slovenia. Significant at that point were the designers and other institutions (specially both universities), which took part at working out estimations about the suitability of the realizations and of the projects in general.

Usage area
General experience with roundabouts in Slovenia do not differ from those in other countries, which have been constructing them for decades. The installation of roundabouts in Slovenia is suitable and recommended mainly at intersections:

- of X, Y and K types (sharp intersection angle);
- of H types (two three-arm junctions close by);
- of larger number of arms (five or more);
- which are especially exposed to arising of traffic accidents with heavy consequences;
- with excessive traffic speeds on approaches;
- on areas, where driving conditions change instantly (i.e. at the ends of high-speed road sections (motorways), at the entries into urban areas, on motorway exits,…) (Picture 3);
- in the case of excessive traffic speeds on major road;
- where posting of traffic lights is, from any reason, not justifiable;
- as a measure of traffic calming.

Thus, in some cases in Slovenia, the installation of a roundabout is the only acceptable solution (for instance intersection of a larger number of arms - five or more). In other cases (in junctions with excessive speeds of entering traffic, in case of sharp intersection angle, measure of traffic calming …), it appears only as one among the number of possibilities. Therefore, there is no universal "prescription", which would determine the usage of roundabouts in Slovenia. Each case is treated separately, according to its own features and circumstances.

Picture 3. Roundabout in Maribor, in front of Štuk
Measures of assuring a traffic-safe roundabout in Slovenia
After examining the suitability of the location and of the position in the global road network, it is necessary in Slovenia, at the modeling of a roundabout, to follow certain instructions (directions), which have a direct influence on the level of traffic safety of all traffic participant. The instructions concern geometrical modeling, which provides transparency, visibility and comprehensibility:

**Arms of a roundabout** should enter the roundabout as right angled as possible (Picture 4). Tangential alignment of an approach into the roundabout causes incomprehensibility of the give-way principle, high approaching speeds of vehicles, obscured visibility at entering the roundabout and collisions of vehicles at entries,

![Picture 4. Arm alignment in the roundabout in Velenje](image1)

**Size of the approach curve**: the speed of an approach depends directly on the approach radius: an excessive radius causes excessive approach speeds, while insufficient radius may cause impacts into the central island or undesirable passages onto the inner lane of the circulatory flow,

**Curvature of the driving curve (deflection)** through the roundabout is of most significant importance for traffic safety at driving through the roundabout. The curve has to have the shape of a double S-curve, which is formed by three radii of adjusted size. Stronger curvature of the curve causes lower driving speed (Picture 5) on approaches and departures and by that greater traffic safety in the roundabout. Deflection can be influenced in two ways: by changing the size of the central island (a better way of changing deflection, but often not feasible) or by changing the shape of pedestrian island (a less effective way, but often feasible)

**Bicyclists**: bicyclists’ safety in roundabouts depends mainly on the method of managing bicyclists’ traffic in the roundabout area, on the method of siting pedestrian islands and on appropriate installation of vertical and horizontal road signs. Separative - independent managing of bicyclists’ traffic in the roundabout area is the safest technique of directing bicyclists. All intersections of motor vehicles with bicyclists (and pedestrians) are performed right angled. Thus the correct form of sight distance is achieved. The only conflict points,
which still remain present, are the crosswalks across the arms of the roundabout, where bicyclists (and pedestrians) are (at least partially) secured by pedestrian islands.

![Picture 5. Stronger curvature - lower driving speed](image)

**Pedestrians:** Pedestrian safety depends mainly on pedestrian crossings and transparency, a little less on the method of installation of pedestrian islands and traffic signs.

**Position of pedestrian crossing and cyclists way crossings:** a distance of one to two passenger car lengths between the outer edge (exit) of the roundabout and the pedestrian crossing is recommended. In this way pedestrians and bicyclists do not strongly obstruct the motor traffic, which enters the circulatory flow and by that, the permeability of the roundabout is higher,

**Pedestrian islands (splitter)** should be adapted to the size of the roundabout and to the expected traffic speed in the roundabout. In great roundabouts, the use of funnel-shaped pedestrian islands is recommended (Picture 6), while in small roundabouts the use cone-shaped islands is the most appropriate,

![Picture 6. Funnel-shaped island in Slovenia’s biggest roundabout, Tomačevo](image)
**Pedestrian under- and over-crossings:** in roundabouts with two or more circulatory flow-traffic lanes (high capacity - great roundabout - high speed limits - worse traffic safety) siting of at-grade pedestrian crossings and cyclists way crossings is not recommendable. In such cases, it is necessary to examine and find an appropriate reason for installing an undercrossing or (more seldom) an overcrossing, which depends on the number and the age group (structure) of pedestrians and on the position of a roundabout in the global road network of the settlement, in which the roundabout is about to be installed.

**Lighting of roundabouts** determines the level of traffic safety at night. The lighting of all arms of the roundabout and of the central island is strongly desired. In large roundabouts lighting columns should be placed at the edge of the central island, while in small roundabouts the lighting in the center of the central island is sufficient (Picture 7);

![Image of a roundabout with lighting](image_url)

**Picture 7. The lighting in small roundabout, Celje**

**Arrangement of the central island** (horticultural arrangement, fountains, monuments and other objects in the central island) is of considerable importance for insuring traffic safety in the roundabout.

Regardless of the esthetic values, the arrangement of the central island has, from traffic safety point of view, also some practical values:

With appropriate shaping of the land inside the central island (or with fountains, monuments, sculptures and other objects) it is possible to clearly warn the drivers, that they are approaching the roundabout,

With partial covering up (hiding) the vehicles on the opposite side of the roundabout, it is possible, without obscuring the necessary visibility, to eliminate the negative effect on the driver, which can be caused by the look on the traffic movement of the entire roundabout.

Plantations in the central island are a good background for traffic signs and direction boards, which are placed on the central island.
Traffic safety in Slovenian roundabouts

The first results of the Slovenian roundabouts’ traffic safety analysis were introduced in 1997, with a precise information on the number and the consequences of traffic accidents, given by the Sector for road traffic of the Ministry of the Internal Affairs. The purpose of the Slovenian roundabouts’ traffic safety analysis was not searching for faults, which might be made by designers. The goal of the analysis was to ascertain the sorts and features of traffic safety phenomena in Slovenian roundabouts and to determine their common negative features. For more concrete evaluation of roundabouts’ traffic safety, one has to be conscious not only of the analysis data, but also of two other circumstances. The first one is the "gray field" - a certain number of traffic accidents, which have not been reported to the police. The second one is that the existing method of collecting and processing the topical traffic safety data (which are being managed electronically by the department of the Ministry of Internal Affairs), has to be accommodated to roundabouts. Because of yet incomplete adjustment of computer data-management it is harder to obtain completely relevant data for particular roundabouts.

From the number of the traffic accident causes on Slovenian roundabouts, traffic speed was the most frequent one (63% of all traffic accidents). The second one was incorrect movements of vehicles, in which the drivers, when changing the traffic lane, did not take necessary measures to assure safe realization of their traffic maneuver (10,1%). The third place goes to the inappropriate safety distance (7,9%) while the fourth belongs to violating the give-way regulation (6,1%). What follows is: incorrect position of the vehicle (4%), incorrect driving direction (1,8%) and finally, vehicles carrying inappropriately loaded freight (0.7%).

The aim of the last part of the article is to present the general level of traffic safety at roundabouts in Slovenia and some of the forms and characteristics of traffic safety incidents at roundabouts in Slovenia today. For this purpose, data has been gathered on the traffic accidents that occurred at the roundabouts that were covered by the analysis of traffic safety that was conducted in 1997.

From the viewpoint of the causes of traffic accidents at roundabouts in Slovenia (since their construction till now) it may be established that most of the traffic accidents (50%) occurred due to excessive speeding. Shifting between lanes represents the second biggest cause (18%) whereby drivers failed to guarantee the safety of their actions while changing lanes. Inadequate safety distance takes the third place (18%) due to which cars collide upon driving on to the roundabout (Picture 8 and 9).

![Traffic Causes Diagram](image.png)

**Picture 8. The causes of traffic accidents at roundabouts in Slovenia since their construction till now**
The comparison of both analyses shows that the percentage of cases of excessive speeding significantly decreased. This indicates that the participants in traffic have got the message and have mastered the rules of driving through roundabouts which, with their appropriately built joining roads, do not allow for high speeding. They, in this way protect the rest of the participants in traffic while at the same time allowing a swift flow of traffic. It may still be observed that drivers pay insufficient attention to driving in the right lane (changing lanes on the roundabout) as the percentage of this cause of accidents has increased (21%).

A review of the results of the analyses shows that traffic safety significantly improved after the introduction of roundabouts and that the roundabouts in Slovenia have, at the beginning of their operation, fulfilled their purpose and have, therefore, justified the expectations. The time period of three years also indicates that the participants in traffic have much better knowledge of the rules of driving through roundabouts.

**Conclusion**

The article is a short summary of the 10-years process of introducing roundabouts into R of Slovenia, which was performed intensively in the last five years. This is a result of several years-studying of foreign regulations, of analyzing their use in R of Slovenia, of working out our own regulations for traffic-technical designing of roundabouts and of monitoring and estimating their suitability on a high number of roundabouts in R of Slovenia.

**Literature**

[1] Technical specification *Krožna križišča (Roundabouts)*, proposal, authors T. Tollazzi, T. Maher, A. Cvar, M. Brezavšček, may 1999

Note: All photographs have been made by the author of the article.
2+1-ROADS WITH CABLE BARRIERS – SAFETY AND TRAFFIC PERFORMANCE RESULTS

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ABSTRACT
The objectives of this paper is to present the SNRA development program to upgrade traffic safety on existing 13 m using low cost measures and also to summarize all important results and findings until April 2001 from opened projects as yet, totally some 200 km.

There is a significant gap in traffic performance, safety, investment and maintenance costs, land requirement and intrusion between normal two-lane and four-lane cross-sections. In Sweden, this gap so far has been filled with a 13 m road with 3.75 m traffic lanes and 2.75 m hard shoulders. The traffic performance of these roads is quite satisfactory but there are safety problems with fatal accidents.

Almost 100 people are killed and about 400 people are severely injured every year on 13 m roads due to the huge traffic load, still being the safest two-lane road. The main problem on all two-lane roads is run-off and meeting accidents causing more than 50 % of all fatalities. The event process tends to be the same. The driver looses control for some reason and crashes against some obstacle in the roadside area or in the shape of an opposing unlucky driver.

In 1998, the director general of SNRA decided on a full-scale programme to improve traffic safety on six existing 13 m roads using low-cost measures preferably within existing right-of-way. The main alternative is the 2+1-solution with a separating cable barrier preferably within the existing width 13 m. This solution was estimated to have a potential to prevent some 50 % of all severe link accidents. Findings so far have been judged so successful that SNRA has decided to replace the old 13 m road with the 2+1-solution on a general basis.

The main results and findings up to May 2001 are as follows:

- Level-of-service for normal traffic is better than expected. Speed performance on 2+1-roads with cable barrier is the same or even better compared with an ordinary semi-motorway at one directional flows up to 1 400 v/h. The capacity is estimated to be about 1 650 v/h in one direction, some 300 v/h less than for an ordinary 13 m road.
- Emergency and tow agencies are complaining as their working conditions and service at emergencies have deteriorated.
- The transitions zones from 2 to 1 lane have performed well. The proportion of vehicles in the beginning of the zone is small. Drivers tend handle the design of the transition zones in a cautious and responsible manner.
- The traffic safety effect on severe accidents was expected to be high on 2+1 road with cable barrier. So far in eight objects there has not been any fatal accident but totally 6 persons with severe injuries. This is about 60 % less than on ordinary semi-motorways and supports the prediction that fatal and severe injuries can be reduced with up to 50%.
- Median cable barrier crashes are very frequent but normally without person injuries. They are often caused by skidding, flat tyre or lost control of the vehicle. A number of accidents have been prevented by means of the median cable barrier but instead turned out to be crashes against the cable with more slight injuries.
- Driver attitude surveys show that drivers attitude to roads with cable barrier have been changed into a positive direction. About 40 % of the drivers say it is the best design.
- The maintenance costs are increased with about 120 Thousand SEK per km and year. The main costs are cable repairs with 80 Thousand SEK per km and year. Work zone safety at cable barrier repairs is a major concern.
1. OBJECTIVES
The objectives of this paper are to
- describe the present 13 m road network in Sweden
- give an overview of the SNRA development program to upgrade traffic safety on existing 13 m two lane roads with 2+1-conversion with median cable barrier as the main tool
- present an overview of all important results and empirical findings until April 2001 from opened projects as yet, totally some 200 km.

2. EXISTING 13 M TWO LANE ROADS IN SWEDEN
There is a significant gap in traffic performance, safety, investment and maintenance costs, land requirement and intrusion between two-lane and four-lane cross-sections. In Sweden, this gap has so far been filled with a 13 m cross-section with two traffic lanes, 3.75 m each, and two hard shoulders, 2.75 m each, with dotted road markings.

Alternative 13 m cross-sections were introduced in the 90’s with the objective to improve safety; partly with 5.5 m lanes and 1.0 m hard shoulders separated with embossed edge markings and partly with road marking based 2+1:designs, i.e. with a middle lane changing direction every 1-2.5 km, see Figure 1.

Fig. 1- Swedish intermediate cross-sections

The national road network, approximately 10 000 km, include some 3 600 km 13 m roads with AADTs varying from 4000 to 20 000 veh/d. Speed limits are mostly 90 or 110 km/h. Only some 300 km are semi-motorways, i.e. grade separated with full access control, no pedestrians, bikers and slow-mowing traffic. The present guidelines give 13 m roads as an opportunity in the traffic interval AADT opening year from 2000 to 12000 veh/d.

2.1 Safety experiences
13 m roads have been found to have some 10 % better safety performance than normal two lane 9 m roads. Wide lanes have turned out not to be a traffic safety success so far (Brüde et al 1996). The very limited Swedish experiences of 2+1-designs with road markings (Brüde et al 1997) have not been by far as promising as the German findings (Brannolte 1993).

Almost 100 people are killed and about 400 people are severely injured every year on 13 m roads due to the huge traffic load. This comprises 25 % of all fatalities and 20 % of all severely injured on national roads (Bergh 1999a). The main problems, more than 50 % of all casualties, on all two-lane roads including 13 m roads are run-off and head-on or meeting accidents. The event process tends to be the same. The driver looses control of his vehicle due to some reason and crashes against some obstacle in the roadside area or in the shape of an opposing unlucky driver. Safety problems seem to be related to lack of concentration, fatigue and monotonous driver perceptions on roads with high standard and low event frequencies.
3. DEVELOPMENT PROGRAM FOR EXISTING 13 M ROADS

In 1998, the director general of SNRA decided on a full-scale program to improve traffic safety on existing 13 m roads using low-cost measures preferably within existing right-of-way, see Figure 2.

The main alternative is the 2+1-solution with a separating cable barrier preferably within the existing width 13 m denoted 13: 2+1cb. A second more costly alternative is to widen up to a narrow 4-lane road; 15.75:2+2cb, primarily in order to improve speed performance and decrease safety risks at vehicle breakdowns and to ease maintenance tasks.

The objectives are to find suitable design procedures, detailed designs and maintenance specifications for these measures and also to validate the positive safety effect estimates, expected to be in the range from 20 to 50 % reduction of severe accidents for 2+1. The program includes intensive follow-up studies of traffic safety, behaviour and attitudes as well as construction and maintenance costs and problems.

<table>
<thead>
<tr>
<th>Road</th>
<th>Object</th>
<th>Measure</th>
<th>AADT</th>
<th>Constr. years</th>
<th>Km</th>
<th>Million SEK</th>
</tr>
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<tr>
<td>E65</td>
<td>Börringe-Skurup</td>
<td>15.75:2+2 cb</td>
<td>9500</td>
<td>00-01</td>
<td>10</td>
<td>100</td>
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<tr>
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<td>Hovsta-Lilla Mon</td>
<td>15.75:2+2 cb</td>
<td>10000</td>
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<td>Häknäs-Stöcksjö</td>
<td>13:2+1 cb</td>
<td>5300</td>
<td>00-01</td>
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<td>Valdemarsv.-Söderköping</td>
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<td>5500</td>
<td>01-02</td>
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<td>60</td>
</tr>
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</table>

1) Name, planned opening year, length and investment cost according to the NSRA proposal on National investment scheme for 1998-2007
2) Forecasts December 1999
3) cb=cable barrier

Fig. 2- Alternative 13 m development projects

4. PRESENT SNRA POLICY

The experiences of the first opened object, E4 Gävle-Axmartavlan, was politically already after 1.5 year judged to be so promising that the director general of SNRA in spring 2000 decided to carry out the 13:2+1cb solution on further about 15 objects. All of these are semi-motorways and located all over the country. Furthermore there have been a few objects on ordinary 13 m road carried out as a 2+1 cb-road. Totally up to the 1 of January 2001 there are more than 200 km of roads opened as 2+1-roads (denoted non-meetings roads).
In Spring 2001 SNRA decided to replace the traditional 13 m road with the 2+1 cable barrier concept as a standard cross-section for new constructions as well as for rehabilitation of existing 13 m roads. The following trigger flow values are used for 2+1-solutions:

- minimum opening year AADT normally 4000 veh/d
- maximum final year AADT 12000 veh/d for normal roads and 15000 for semi-motorways

The counter-measure should also:

- be appropriate for the problem situation
- give a reasonable cost-benefit ratio
- give a reasonable traffic safety key value, i.e. cost per reduced severe or fatal injury
- give a reasonable level-of-service during the final year design hour

5. DESIGN CONCEPT

The design concept for a 2+1-design with cable barrier on an existing 13 m road is as follows:

- One continuous lane in each direction and one middle lane changing permitted direction with an interval of 1.5-2.5 km. The length depends on alignment, locations of intersections etc. 1+1-designs could be used at long bridges expensive to widen and on sections with frequent access roads, pedestrians and bicyclists where separation is costly or impossible. 2+2-sections could also be needed to avoid 1-lane sections on up-hills and to improve traffic performance on segments with low costs for widening.
- Transition zones from 2 to 1 lanes have a length of 150 m, totally 300 m for both directions. The transition zone has delineators on the cable poles at a distance of 10 m with double-sided lane closure information signs 400 m ahead and at the start of the transition zone, see Figure 3. Quick-locks make it possible to open the cable barrier in each transition. Transition zones from 1 to 2 lanes are 100 m.

Fig 3- Design principles for 2 to 1 lane transition zone

- The cross-section within the existing 13 m on normal 13 m roads, see Figure 4, is proposed to comprise of:
  - 1.25 m median with a continuous cable barrier in CEN containment class N2 and working width W5
- 3.25 m wide traffic lanes in the two-lane direction and 3.75 in the one-lane direction
- 0.75 m outer hard shoulders to facilitate very low volume pedestrians and bicyclists.
- a strip of 1.0 m with full bearing capacity without overlay on one-lane sections for emergencies can be added.

**Fig. 4- Proposed standard 2+1-cable barrier cross-section within existing 13 m**

- Existing roadside areas should be smoothed within the right-of-way. This means that solid objects, trees etc should be taken away and culvert ends tapered. Side cable barriers should be used at dangerous locations as right bends in rock cuts and on low cuts and all embankments in forest areas, see *Figure 5.*

**Fig. 5- Example of side cable fence in a forest area**

- The maintenance standard includes the following requirements:
  - Bridge inspections, overlay repairs etc should be co-ordinated to minimize the number of traffic diversions. Delineator post washing etc should be performed during low traffic volume conditions
  - snow should be removed in the first 0.4 m of the median. Edge lines should be visible.
- Permanent emergency openings is to be established every 3-5 km in the cable barrier to allow rescue vehicles to turn
- Cable barrier ends used are tested and approved. They don’t cause any ramp effects.

Access roads should be taken away and pedestrians and bikers should be separated when possible at reasonable costs.
Major critical issues are conditions for access traffic and vulnerable road users and the narrow one lane sections. The latter, some 5 m if the road is not widened, will create road blockages at emergency truck stops, deteriorate emergency services and conditions for maintenance.

6. SPEED PERFORMANCE FINDINGS

A feasibility study, performed before the development program was started, predicted passenger free flow car speeds to decrease a few km/h with a rather big flow impact based on experiences on 2+1 road marking designs and simulations (Brüde and Carlsson 1997).

On E4 Gävle-Axmartavlan speed effects have been investigated by means of:

- a number of before and after spot speed measurements
- floating car studies in high traffic volumes
- continuous lane based spot speed measurements on a location for southbound at the start of a one lane section and for northbound at the end of a two lane section.

The main conclusions from measurements at speed limit 90 km/h (1998-1999) and speed limit 110 km/h (1999-2000) are (Carlsson et al 2000 and 2001):

- Daily average journey speeds for cars have increased about 2 km/h at speed limit 90 km/h
- The journey speeds have increased further at introduction of speed limit 110 km/h. The average journey speeds for cars are 108,5 km/h with a difference of about 5 km/h between one lane and two lanes segments (111 km/h in two lanes and 106 km/h in one lane segments).
- This is valid for one directional flows up to 500 v/h. At higher flows the speed is weakly decreasing in one lane segments
- The speeds for cars in overtaking lane on two lanes segments are in average 120 km/h.
- At one directional flows above 900 v/h there is considerable variations in speed profile between the different segments
- Floating car studies confirm a good level-of-service also at high traffic flows, up to 1 300-1 400 v/h in one direction
- The capacity is estimated to be 1 600-1 700 v/h in one direction during a 15 minutes period. This value is estimated to be some 300 v/h less than for an ordinary 13 m road.

The transition zones from 2 to 1 lane was feared to get both weaving and trafficability problems. So far the transitions zones have performed well. The proportion of vehicles in the beginning of the zone is small on 2+1 cb, significantly smaller than on 2+1 based with road markings. The conclusion is that drivers seem to handle the design of the transition zones in a cautious and responsible manner.

Traffic flows in the range 1 200-1 350 v/h with average speeds 100 km/h have been measured at the beginning of a one lane segment at speed limit 110 km/h, see Figure 6. Continuous lane based spot speed measurements have been carried out during nine weeks in April-June 2001, covering all the big holidays with high traffic volumes. The flow impact seems to be very low, partly due to the measure point location. As can be observed there is no flow impact for flows below 700 v/h. The maximum hourly flows correspond to 30-35 % of the AADT for this direction. The capacity is estimated in the range 1 600-1 700 v/h.
At one occasion with extremely high traffic volumes at Easter year 2000 a capacity breakdown has occurred. The transition zones from 2 to 1 lane were over saturated at weaving to one lane with long platoons and stop and go conditions as a consequence.

![Graph of Hourly car average speeds versus directional total flow (v/h) at the start of a one-lane section.](image)

**Fig 6– Hourly car average speeds versus directional total flow (v/h) at the start of a one-lane section**

### 7. TRAFFIC SAFETY FINDINGS

#### 7.1 Accident analyse and conclusions

The main reason with the 2+1-design with median cable barrier is obviously to decrease the number of meeting- and overtaking accidents with severe and fatal consequences. In the feasibility study cable separation and smoothing of the roadside was estimated to reduce severely injured and killed in the range 20-50 %, higher on semi-motorways than on normal roads. This should be compared with a full extension to motorway with a reduction of 65 %, which reasonably must be the maximum effect. But on the other hand it was judged that the number of slight accidents without personal injuries should increase depending of the median cable and narrow one lane segments.

For a general safety analysis all accidents that have occurred on all the opened objects with median cable have been summarised. The outcome up to 1 May 2001 has been considered. That makes totally 121 accidents with **no one killed and 6 persons with severe injuries**. The 121 accidents are distributed on type of accident as follows:

- 69 single accidents with 5 severely and 18 slightly injured persons
- 29 overtaking accidents with 5 slightly injured
- 14 catching up accidents with 8 slightly injured
- 9 various accident with 1 severely injured (sudden braking for a bird)
Of the totally 121 accidents 24 have involved personal injuries. Of these 24 accidents 12 have occurred in two lanes segments and 11 in one lane (one is unknown). There is no basis to declare that one lane segments are more dangerous than two lanes.

As can be observed the meeting accidents have so far ceased disappeared and the number of single accidents with severe injuries have been significantly reduced (totally 3 accidents with 5 severely injured persons, all in right hand run off accidents). But there has been one single accident, where the vehicle passed over the cable barrier and crashed in the ditch on the other side of the road. All persons involved were belted. This and some help from heaven gave only one slight injury among five people in the car.

Overtaking accidents with severe consequences have not appeared as yet but normally these accidents are just about 6 % of all severe injuries. A reasonable conclusion of the data presented above is that accidents with severe consequences have been prevented of the cable barrier and converted to cable crashes without any severe consequences. That is valid especially for meeting accidents but also for single accidents, which in general have significantly less severe injuries.

The safety outcome presented above has been compared with the normal (predicted) outcome on ordinary semi-motorways with the same traffic volume. The 121 accidents presented above are the outcome on eight opened semi-motorway objects with totally 364 millions axle pair km of mileage.

The SNRA safety prediction model (SNRA 2000), used in the cost-benefit calculation program for investment planning, has been used for calculation of the normal (predicted) outcome on an ordinary semi-motorway link with speed limit 90 or 110 km/h. Table 1 below presents the predicted number of accidents and number of injured and killed persons. The predicted values are compared with the real outcome (observed numbers) on the eight opened objects.

Table 1- Predicted number of accidents and injuries compared to real outcome

<table>
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<tr>
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<th>Predicted</th>
<th>Observed</th>
<th>Remark</th>
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<tbody>
<tr>
<td>Number of acc.</td>
<td>80</td>
<td>121</td>
<td>Significantly more</td>
</tr>
<tr>
<td>Injured persons</td>
<td>50</td>
<td>37</td>
<td>No significant differ.</td>
</tr>
<tr>
<td>Severe injured or</td>
<td>14.2</td>
<td>6</td>
<td>Significant on the limit</td>
</tr>
<tr>
<td>killed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Killed</td>
<td>3.9</td>
<td>0</td>
<td>No significant differ.</td>
</tr>
</tbody>
</table>

There are 6 severe injured including killed from all the objects and from the 364 millions axle pair km of mileage. That should give an effect of about 58 % (8.2 compared to 14.2). The observed number is significantly different from the predicted one, but just on the limit. The estimated effect of 58 % are composed by the median cable barrier of about 45 percent units and the roadside smoothing of about 13 units. As already mentioned no one has been killed but that is still not but close to a significant difference to the predicted value 3.9.

Total numbers of injured are about 25 % less than predicted but the total numbers of accidents are higher than normal number (about 50 % higher, significant difference). But this is in agreement with the expectations in the feasibility study.
The results in table 1 give a basis for a smooth adjustment of the initial judgement in the feasibility study for semi-motorways. The effect on severe injured and killed persons can now be estimated to be from at least 30\% and up to 50\% (with roadside smoothing). The effect for killed persons is probably higher than 50\%. The effect for extension to motorway is 80\%. No accident data is available so far for ordinary 13 m roads.

7.2 Median cable crashes
It was expected that the number of median cable crashes should be high, in the range 0.5-1.0 crashes per million axle pair km.

The outcome so far is 0.8 on E4 Gävle-Axmartavlan, which means 159 crashes or about once a week on this road. About 30\% of the crashes are reported to the police and can be investigated. Only 30\% of these reported crashes were primary direct cable crashes probably caused by lack of concentration. All other cases were preceded by skidding, flat tyres, uncontrolled manoeuvres including position outside right asphalt edge and similar.

Other information about cable crashes of interest is as follows:

- 65\% have occurred in one lane segments
- Just 8\% have occurred in a transition zone 2 to 1 lane. This is a slightly less proportion than the length of road with 2 to 1 transition (about 10\%).
- About 50\% of the crashes have occurred in the winter period, December-March. The proportion of the yearly mileage during these months is just 25\%. In many cases skidding is the primary cause for a cable crash.
- Barrier crashes is a winter problem

Some data has also been reported from other projects. The variation tends to be significant between individual projects. A lot of effort has been spent on embedded noise producing road markings and visual devices on the barrier to reduce the number of crashes.

The main conclusion is that a number of accidents have been prevented of the median cable barrier but instead turned out to be crashes against the cable with in many cases more slight injuries.

8. DRIVER ATTITUDES
On the first object E4 Gävle-Axmartavlan driver attitude surveys were performed during two occasions, autumn 1998 and autumn 1999. Some results are (Carlsson et al 2000 and 2001):

- The survey from autumn 1998 showed that the drivers prefer 2+1-design with road markings to an ordinary two-lane road. Only a marginal number had the 2+1 with cable barrier as the best alternative, less than 1\%.
- At the new survey autumn 1999 about 40\% of the drivers considered 2+1 with cable barrier to be the best design against 30\%, which prefer 2+1 with road markings. The changes in attitudes are large and significant. The changes were greatest amongst personal car drivers who were interviewed at the roadside, which include a big proportion of non-local traffic.
- It is obvious that the people in the survey, both the roadside drivers and local people answering by mail, have changed its attitude against the 2+1 road with cable barrier. From a general very negative attitude against it to a general accept of the design, based on the own experiences during one year of driving.
A major attitude survey has also been conducted on E18 with even better results.

9. IMPACT ON MAINTENANCE
The additional costs for maintenance on 2+1-roads with median cable are presented in (Carlsson 2000 and 2001). The total maintenance costs are estimated to increase with about 120 Thousand SEK per km and year for E4 Gävle-Axmartavlan, rather close to a 100% increase. But this is slightly lower compared with the estimations in the feasibility study. The main additional costs are summarised below:

- Cable repair costs is the largest problem. The costs for one cable crash are about 10 000 SEK for cable repair and 25 000 SEK for car repair, totally 35 000 SEK. The latter figure is a guess as no data are available. A cable crash rate of 0.8 per millions axle pair km gives about 2.3 crashes per km road length and year. This is corresponding to 80 Thousand SEK per km and year.
- Opinions vary about pavement costs. Based on rut depth measurements pavement costs are estimated to increase with about 10 Thousand SEK per km and year. The reason is more rutting in the one-lane segments.
- Normal fixed works as delineator post washing, bridge washing, ditches and roadside cultivation is recommended to be performed during low traffic volume conditions. On E4 Gävle-Axmartavlan these tasks are carried out with one-way traffic with the other direction redirected to a parallel road by means of stationary redirectional signs and VMS-signs on the entries to E4. The additional costs are estimated to 20 Thousand SEK per km and year.
- Winter maintenance costs are increased with just 5-10 Thousand SEK per km and year. This is far less than expected. The snow ploughing speed is unaffected but snowplough drivers complain that the task is more stressing than normal ploughing. The salt consumption has decreased instead of increasing. The reason is that it is now a somewhat smaller surface to be salted.

Work zone area safety is a major concern. Repair work is so far conducted from a TMA-closed overtaking lane with full traffic in one lane in both directions. One serious incident has occurred when a passenger car crashed the road lane closure device in high speed. Another one is emergency blockages and emergency vehicle operation.
REFERENCES
THE NEW APPROACH TO TRAFFIC PLANNING
AND STREET DESIGN
- GROWTH, ACCOUNT AND IMPLEMENTATION

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1. GROWTH OF NEW STREET TYPES IN BUILT-UP AREAS DURING THE LATTER PART OF THE 20\textsuperscript{TH} CENTURY

1.1 50 km/h in Built-up Areas
50 km/h has been the general basic speed in built-up areas in Sweden since 1950. Deviations from this speed occur only on exception, despite the fact that the traffic planning documents used in Sweden during the latter half of the 20\textsuperscript{th} century present a very clear hierarchy of street types in built-up areas. This causes tension. There are many cases where a speed of 50 km/h is considered too high, for example on many entrances to areas with one-family dwellings and on several residential streets in central city areas. In other instances, a speed of 50 km/h in built-up areas seems too low.

1.2 Traffic Segregation according to the Scaft Guidelines
The Scaft principles have had a great impact in Sweden. The concepts involved were associated with what is modern, right and desirable for a long time. Traffic segregation was seen as something that had to be applied everywhere, and something that would be successful in new development areas, but not in older established areas. Sweden ignored established areas, and unlike countries like Holland and Denmark did not promote a mixed traffic system.

1.3 Development of New Street Types
New types of street started to emerge during the second half of the 20\textsuperscript{th} century in northern Europe.

Pedestrian precincts were introduced in city centres at the end of the 50’s. Ströget in Copenhagen is an example of this. This development began in the 60’s in Sweden.

The end of the 70’s saw the woonerf being introduced in Holland. This was known as leg- og opholdsgade in Denmark in the 80’s and as gårdsruta in Sweden and gatetun in Norway in the 90’s.

30-streets started appearing on the scene. The idea that 30 km/h should be the maximum speed in residential areas gained momentum in many countries along with the view that these areas should consist of 30-streets and walking speed streets (pedestrian precincts and woon-erfs). In Denmark 30-streets were called Stillevej. In the mid-80’s a decision was made in Holland to slow down the introduction of woonerfs and concentrate more on 30-areas. The Dutch are strongly in favour of the woonerf, but it is a very expensive alternative. In the mid-90’s Graz decided to introduce 30 km/h throughout the entire city, except on streets marked as primary roads where the basic speed was 50 km/h. A few streets also had a posted speed of 60 km/h.

50/30 streets started being built. To my knowledge, the first of these was Skiphusvej in Odense, a conversion that began in 1979. Using Skiphusvej as a model, Drottninggatan and Djurgårdsgratan in Linköping were converted at the end of the 80’s. The 90’s saw Slottsskogsgratan and Djurgårdsgratan in Gothenburg move in the same direction. A 50/30 street is meant to refer to a main street on which more or less extensive civil works are undertaken at certain points in order to reduce vehicle speeds and thereby make it easier for pedestrians, cyclists, children, senior citizens and disabled persons to cross over. These traffic-calming measures force cars to shift in a horizontal and/or vertical direction. The street width can also be reduced; Drottninggatan in Linköping for example was reduced from 10.5 m to 6.2 m. A narrower vehicle carriageway often makes it easier to create cycle paths or plant trees. Asphalt is frequently replaced by other materials that make the street environment more attractive while facilitating separation, primarily between pedestrians and cyclists.
2. VISION ZERO

The lack of safety in the road transport system has gradually developed to a major, and global, public health problem. Reductions have been seen in some countries, but not to the extent that the road transport system can be said to be Safe. For a long time the goal in traffic safety policies has been a continues decrease in fatality rates. The ultimate goal then per definition is set to zero fatalities.

A concept called the “Vision Zero” has developed in Sweden. The Vision Zero defines the traffic safety problem, not as a crash problem but instead as an injury problem. Fatalities and severe/impairing injuries are focused. Property damages and minor injuries are not considered first priority problems.

The safety philosophy behind the Vision Zero is not to allow mobility over the limit for the risk of being killed or seriously injured, and to build a system that is forgiving to human mistakes and misjudgements. This is partly different from the philosophy of yesterday, where the road users are supposed to act perfect within the road transport system.

To radically change the situation the traffic system must be redesigned to be more forgiving to mistakes of the road users.

Compared to other man/machine systems the traffic safety system is very little developed. The human tolerances to extreme forces are limited and to a large extent know. If designing a transport system to the biomechanical limits on human beings, changes in many approaches of today must be made. A theoretical model for the transport system has been developed. The introduction of the Vision Zero on the political area has been successful. In the long time planning process the Vision Zero has become very important in Sweden.

According to Vision Zero, the level of violence that the human body can tolerate without being killed or seriously injured shall be the basic parameter in the design of the whole road transport system. And of course also in the creating of a traffic network and street design in build-up areas. According to this we have stated three important premises for road safety and street design

1. On roads where there is a risk for head-on collision
   a motor vehicle is not allowed to drive faster than 70 km/h.
2. On streets where there is a risk for a side impact collision
   a motor vehicle is not allowed to drive faster than 50 km/h.
3. On streets where a car can hit a pedestrian or a bicyclist
   a motor vehicle is not allowed to drive faster than 30 km/h.

More or less as a logical consequence of these three basic premises, a hierarchical division of streets and roads has been introduced as follows

1. Through Traffic Route (70 km/h roads)
2. 50/30 Street (Main Street)
3. 30 Street (Residential Street, Wohnstrasse, Rue Residentielle)
4. Walking Speed Street (Woonerf)
5. Car Free Area (lanes for pedestrians and cycles, pavement, cycle path, square etc)

So, results can already be seen in development of the new street design types above, The New Approach.

In other words, we change the standard 50 Streets in built-up areas to 50/30 Streets, 30 Streets and Walking Speed Streets wherever pedestrians, cyclists and motor vehicles share the street.
3. ACCOUNT OF THE NEW APPROACH

3.0 Introduction

On a number of occasions, the Swedish Government and Parliament have expressed various goals that are to be met within the framework of the transport system. These goals mainly relate to a high degree of road safety, good traffic environment, good transport quality, good accessibility for commerce and industry and the private individual and a good regional balance.

In addition, Government and Parliament wish us to achieve a greater proportion of pedestrian and cycle traffic. Government and Parliament also wish us to achieve a much better situation for children, the elderly and the disabled when it comes to their ease of movement, safety and security.

The goals for road safety are a maximum of 400 fatalities and 3,700 seriously injured in 2000, and a maximum of 250 fatalities in 2007. The long-term goal of Vision Zero is a situation with no fatalities and no seriously injured in road traffic.

Work is under way to break down the goals expressed by Government and Parliament into specific components. The New Approach is to be seen as part of this work. The content of the New Approach will form the main part of the remainder of my presentation.

In many European countries, perhaps especially in Sweden and in the Netherlands, the conviction arose that the current policy on road safety was no longer capable of reducing the present level of risk, and that a new and radical future scenario had to be defined to improve the situation. Both the concepts of “Vision Zero” (Sweden) and “Sustainable Safety” (the Netherlands) state that if we wish to change the road safety situation radically, we must stop defining road fatalities as a negative, albeit largely accepted, side effect of the road transport system. Both concepts describe the road safety problem as a public health problem, which can no longer be ignored.

Central elements of the Swedish Vision Zero/The New Approach and the Dutch Sustainable Road Safety System are regard to the intended function of and the intended (traffic) behaviour on the roads that are being planned. The design has to comply with the demands of function and behaviour. If function, design and behaviour are not well balanced, adjustments in one, two or all three of them have to be made to find a proper balance.

In both Vision Zero/The New Approach (Sweden) and Sustainable Safety (The Netherlands) the classification in different road and street types with well-described characteristics is considered to be a very important aspect.

The concept of the New Approach is characterised by

1. A limited number of categories of urban roads and streets
2. Clearly distinctive design
3. Distinctly different types of roads and streets
4. The design of the road categories must be easily recognisable.
5. The design alternatives will be limited to create uniformity.

So, when you are in a street you should be able to understand,
preferably intuitively
1. What kind of street you are in.
2. What (traffic) behaviour is expected from you.
3. What (traffic) behaviour you can expect from others.
You shall be able to understand it even if you are a child, an elderly or a disabled person.

According to Vision Zero, speed is regarded as a very important and integral factor. So, from traffic safety point of view it is said that:
1. On roads where there is a risk for a head-on collision
   a car is not allowed to drive faster than 70 km/h.
2. On streets where there is a risk for a side impact collision
   a car is not allowed to drive faster than 50 km/h.
3. On streets where there is a risk for a car to hit a pedestrian or a bicyclist
   a car is not allowed to drive faster than 30 km/h.

More or less as a logical consequence of these basic premises, a hierarchical division of streets and roads has been introduced in Sweden as follows:
1. **Through Traffic Route** (70 km/h Road, sometimes 50 Road or 90 Road)
2. **50/30-Street** (Main Street, Urban Arterial Road)
3. **30-Street** (Residential Street, Wohnstrasse, Rue Residentielle)
4. **Walking Speed Street** (Woonerf).
5. **Car Free Area** (not dealt with here)

We are now presenting a system of street classification. One advantage of this road and street classification is the possibility of including an accurate description concerning
**Function** (perspective of society)
**Behaviour** (perspective of individuals/road users)
**Design**
for each street type.
3.1. Through Traffic Route

Function
The through traffic route is intended for longer motor-vehicle journeys through built-up areas passing by one or more residential areas. The through traffic routes consist of those roads where priority is given to the efficient transport of people and goods by motor-vehicle at steady, moderate speeds within a road network capable of handling the prevalent traffic volume.

Behaviour
The speed of motor vehicles is mostly 70 km/h on through traffic routes. The speed at intersections may not exceed 50 km/h if there is any risk of a side impact collision. This is ensured through traffic calming measures as roundabouts, or - ultimately – through road informatics technology. If there are short distances between the intersections, the speed limit is restricted to 50 km/h, even on unbroken stretches. The speed limit is ensured through a traffic calming design, even on unbroken stretches. Often the speed limit is also felt to be well motivated due to the relative proximity of housing developments.

The speed of 90 km/h is sometimes possible even in built-up areas if the alignment and the intersections are of very high standard, and if the distances between intersections are long. Pedestrians and cyclists pass through traffic routes at grade-separated crossings. If this is not possible, motor vehicles pass pedestrian and cyclist crossings at 30 km/h, the speed ensured with the help of measures such as roundabouts.

Design
The alignment of a through traffic route is often of high standard and as far away from nearby buildings as possible. The through traffic route is often situated in suburban areas or on the periphery of built-up areas. The carriageway often has two traffic lanes for motor-vehicle traffic in each direction, sometimes even more. There is often road space available to enhance the safety of errant vehicles. Rigid, stationary objects in the roadside area have been positioned, designed or shielded so as to protect motorists who unintentionally drive off the carriageway from serious injury in the event of head-on collision or side impact collision.

The carriageway has often two lanes for motor vehicle traffic in each direction, sometimes even more.

A through traffic route is segregated from pedestrians and bicyclists, and any road connection to adjacent neighbourhoods is intended for motor-vehicle traffic only. As there are no pedestrians or cyclists on a Through traffic route, there are no pedestrian pavements and no cycle-tracks.

Pedestrians and cyclists are provided with an adequate number of grade-separated interchanges for crossing through traffic routes. For movements parallel to the Through traffic route network, there are pedestrian and cycle paths that are totally segregated from motor-vehicle traffic by means such as vegetation, a safety fence or sufficient distance between the carriageway and the pedestrian and cycle path.

Green ways running along through traffic routes often have very few or even no points of confrontation with motor vehicles. Their alignment is often attractive for fast-moving, long-distance bicycling. This means that they would be a natural component in the trunk cycle network.
3.2 50/30 Street

Function
The 50/30 street is used by motor vehicles and by bicyclists going from one neighbourhood to another nearby or -for motor vehicles - to a Through traffic route. Car parking can be permitted along a 50/30 street, especially in central areas.

Often a 50/30 street is not a boundary between two neighbourhoods, and therefore pedestrians, cyclists, children, the elderly and disabled persons very often need to cross 50/30 streets.

Behaviour
Pedestrians and cyclists cross a 50/30 street at designated pedestrian and bicycle crossing. Car drivers pass pedestrian and bicycle crossing not faster than 30 km/h.

On unbroken stretches where no pedestrians or cyclists cross, motor vehicles are permitted to drive a maximum of 50 km/h.

Design
The carriageway normally has only two lanes for ordinary motor-vehicle traffic, one lane in each direction. This means an approximate width of 6.2 metres between the kerbs on opposite sides of the street. The 50/30 street has wide pedestrian pavements and wide bicycle tracks affording pedestrians and cyclist good accessibility, safety and security.

There are three very important reasons for constructing cycle-tracks along 50/30 streets. It promotes bicycling and safety, and it enables road-users to intuitively perceive that they are in a 50/30 street.

So, the 50/30 street has wide cycle-tracks and wide pedestrian pavements, affording pedestrians and cyclists ease of movement, safety and security. Furthermore, these wide pedestrian pavement and cycle-tracks provide the potential for creating an attractive, pleasant street space that is also suitable for children, the elderly and disabled persons.

50/30 streets often have a straight, direct alignment. The cycle-tracks along these streets will therefore almost of necessity become a natural link in the trunk bicycle network. This means that they will be at least 2 metres wide for one-way cycle traffic and at least 4 metres wide for two-way cycle traffic. The high biking speed also motivates the necessity of taking measures to separate pedestrians and cyclists. A sufficiently wide pedestrian pavement and a sufficiently wide cycle-track should then be arranged; 2 metres would appear to be an acceptable minimum for both the pavement and the cycle-track.

Where there is heavy bus traffic, the 50/30 street is designed with bus lanes.
3.3 30-Street

Function
The 30 street is a street mostly in a residential area, where priority is given to the local inhabitants, thus designating its function. The 30 street is an attractive, pleasant street space and an environment suitable for children, the elderly and disabled persons.
As far as vehicles are concerned, a 30 street is used mostly by local motor-vehicle traffic that originates in or has a destination within the neighbourhood. As regards motorised vehicles, 30 streets nearly always have access traffic, sometimes collector traffic, but no through traffic. For cyclists, 30 streets may have a distribution and also a through traffic function, since cyclists need smaller margins in their network.

Behaviour
Within a residential area it is natural to cross a street as a pedestrian or a cyclist arbitrarily, either anywhere along the street or at street crossings.
The normal way to move within a 30 area is on foot or by bike. It is safe and secure to go by walking canes, wheelchairs and rollators. Rollators is a walking aid very common in Sweden. On 30 streets the speed is limited to a maximum of 30 km/h. Where motor vehicles and cycles share the same space, and where a 30 street has an obvious residential function, lower speeds should probably be recommended for both cyclists and motorists.
The cyclists can use the entire width of a 30 street and motor vehicles can be required to wait before overtaking until this can be performed without risk of danger.

Design
A 30 street has pedestrian pavements and a carriageway. The carriageway is as narrow as possible, i.e. between four and six metres. Thus, there is space for the pedestrian pavement to be as wide as possible, providing great potential for creating an attractive, pleasant street area suitable for children, the elderly and disabled persons alike. Especially in the inner city areas, 30 streets provide part of the need for short-time parking. Parking spaces are designed and located with care, paying consideration to their being an aesthetically attractive element within the street environment.
The 30 street has no marked pedestrian and cycle crossing, no cycle tracks and no traffic signals. Sometimes there are cycle roads in 30 areas.
Traffic calming measures guarantee safe, secure interaction between pedestrians, cyclists and motorists. A good traffic calming measure is an elevated crossing, signalling that in residential areas priority is given to pedestrians. Motor vehicles pass an elevated crossing at walking speed. This solution will help children, the elderly and disabled persons to move about, especially those in wheelchairs and using rollators.
30 streets are designed with varying kinds and levels of traffic-calming measures.
It is not out of the ordinary that a 30 street is made one-way for motor vehicles in a 30 km/h area. However, it is not usually necessary to make such a street one-way for cyclists as well. Depending on the situation, it could suffice to simply use signs to indicate that bi-directional traffic for cyclists is permitted. However, it could also be necessary to use both signs and a painted line to delineate a cycle lane in the direction facing oncoming motor-vehicle traffic, i.e. what is known as a “contra-flow lane”. It would be appropriate to construct this cycle lane in a material and colour associated with cycling, e.g. reddish brown asphalt. A traffic island could be required at the beginning and at the end of the cycle lane. When the traffic volume is intensive on such a one-way street, it may be necessary to construct a curb cut to separate the cycle traffic facing oncoming motor vehicles.
A cycle street can cut across a 30 km/h area. Such cycle streets are characterised by distinctly more through cycle traffic than what can be found on a normal 30 street. One possible reason for this situation could be that the 50/30 streets in the vicinity are so far apart that they are unable to capture all the fast-moving bicycle traffic on the cycle-tracks. Cycling is very much affected by detours, and therefore needs more direct routes. Another reason could be that the cycle-tracks along the 50/30 streets have not yet been constructed for some reason or another. Cyclists along a cycle street have the right of way at intersections within a 30 km/h area. Motor vehicles cross cycle streets at walking speed.

3.4 Walking Speed Street

Function
The walking speed street is a communal outdoor space shared by everyone living by the street. It is a street especially for children, the elderly and disabled persons. A walking speed street is an attractive, pleasant street space for meetings, play and recreation. It is used by motor vehicles only when they come from a destination or go to a destination along it or a street close nearby.

Behaviour
Pedestrians and cyclists always have the right of way.
The walking speed street is designed and regulated so that the maximum speed for motor vehicles does not exceed walking speeds, i.e. 5 to 10 kilometres per hour, with an average speed of around 7 kilometres per hour depending on who is walking.
This type of street has often been created on the initiative of the property owners and the local residents, with both groups supporting the construction and maintenance operations.
Needless to say, it is safe and secure to bicycle on a walking speed street since the speed of the motor vehicles is limited to walking speeds. Children, elderly, disabled persons and those not used to cycling ought particularly to appreciate being able to cycle here. The major purpose of walking-speed streets - i.e. being a pleasant and attractive outdoor area for those living and working along the street or in its immediate proximity - means that it cannot be used for biking at very high speeds and to a very great extent.
The disadvantage of walking speed streets means that cyclists do not have to travel at walking speed for more than maximum one or two hundred metres, and this normally occurs at the beginning and at the end of a trip.

Design
The walking speed street is designated as communal outdoor space shared by everyone living by the street.
The entire walking speed street is intended for everybody; it is not divided into separate lanes for different types of “traffic”.
It is designed entirely at the same level, i.e. there are no curbs.
It is a good solution if the pavement surface is in a colour generally associated with walking, preferably light grey, and in a material we associate with walking, for instance plates, bricks or stones.

3.5 Car Free Area (not dealt with here)

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4. IMPLEMENTATION. FROM VISION TO REALITY

4.1 The Swedish National Road Safety Programme and A New Design Philosophy for Urban Streets

The National Road Safety Programme for 1995-2000 stipulated the development of a new design philosophy for urban streets. This was subsequently drawn up by the Swedish National Road Administration in 1996. A concentrated version of this was presented in Chapter 3, entitled "Envisioned Goals", in the reform document "Safer Traffic Environments in Built-up Areas" published jointly by the National Police Board, the Swedish Association of Local Authorities and the Swedish National Road Administration in March 1997.

Initially, 4 000 copies of this document were printed. However, the demand was far greater than expected, and before the end of 1997, 23 000 copies of this "orange book" (as it came to be called) were printed. It became evident that the knowledge and recommendations presented there filled a great need.

1999 saw the publication of a manual entitled "Calm Streets!", which is primarily a method to assist in the classification of municipal streets along the lines of the New Approach. The municipalities of Tjärhamn, Borås and Nora took the lead in implementing this approach. The results are compiled in three easily comprehensible and pedagogical reports that have been distributed to all Swedish municipalities. Financial backing was provided by the Swedish National Road Administration (SNRA).

4.2 SNRA Regional Administrations and The New Approach

The SNRA regional administrations have been positive towards the New Approach, and have decided that it would be preferable to work according to its envisioned goals rather than according to the provisions in such documents as Argus ‘87.

These regional administrations have allocated a substantial amount of time and money to help municipalities classify their streets according to the "Calm Streets!" method. Some regions have expressed the desire that the reform document be given formal support within the SNRA. This will probably not happen, and it is not certain whether such formal support is necessary or even desirable.

4.3 Swedish Association of Local Authorities and the New Approach in "Calm Streets!"

The Swedish Association of Local Authorities is actively working on the reform document "Safer Traffic Environments in Built-up Areas". This association is the sole publisher of "Calm Streets!", which is fully behind the New Approach that was first presented in the reform document.
4.4 Municipalities and the New Approach

Most of the municipalities in Sweden have either classified their streets according to the New Approach or are in the process of doing so. This is largely due to the fact that several municipalities already had intended to work in quite a similar direction.

The street classification is usually related to and co-ordinated with overall urban planning, and often has firm political backing.

4.5 New Approach and Operational Planning

For the past few years, the SNRA has used either the number or percentage of municipalities that have classified their street network according to the structure presented in "Safer Traffic Environments in Built-up Areas" and in "Calm Streets!" as a parameter in its annual operational planning for the coming year. Hence, the SNRA Head Office along with the regional administrations have not only espoused the New Approach but have also decided to work from its basic premises and endeavour to turn it into reality.

4.6 EU Project Promising and the New Approach

Part of the work in the European Union project Promising concerns trying to create a desirable framework for street structure and design in built-up areas. The discussions in this connection primarily concern ideas and results from both the Dutch "Sustainable Safety" as well as from the Swedish "Vision Zero" in its application to street structure and design: the New Approach. The New Approach is presented on pages 59-63 in the main report of the Promising project and on pages 20-34 in the WP2 report.
5. REFERENCES  (in chronological order)


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Per Wramborg
ADVANTAGES OF OFFSET T-INTERSECTIONS
WITH GUIDELINES

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BACKGROUND
Intersection safety constitutes one of the most critical elements of the highway system in the United States. About 23 percent of fatalities and 49 percent of highway injuries occur at intersections, both signalized and non-signalized. Injury and total crashes are equally represented at signalized and non-signalized intersections (table 1). Although there are a larger number of non-signalized intersections, the magnitude of the exposure might be comparable to signalized intersections. A higher percentage of fatal crashes at non-signalized intersections (table 1) may be attributed to higher speeds.

Table 1. Type and Location of Crashes Nationwide *(Traffic Safety Facts 1999)*

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Intersection and Intersection-Related</th>
<th>At Signalized Intersections</th>
<th>At Non-Signalized Intersections &amp; Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>8,514 (23%)</td>
<td>2,734 (32%)</td>
<td>5,780 (68%)</td>
</tr>
<tr>
<td>Injury</td>
<td>1,015,000 (49%)</td>
<td>476,000 (47%)</td>
<td>539,000 (53%)</td>
</tr>
<tr>
<td>Total</td>
<td>2,806,000 (45%)</td>
<td>1,279,000 (46%)</td>
<td>1,527,000 (54%)</td>
</tr>
</tbody>
</table>

Single-vehicle crashes account for approximately 24 percent of the crashes at non-signalized rural T-intersections and 13 percent of the crashes at four-legged intersections (two-way stop-controlled [TWSC]) (Bauer et al., 2000). In urban areas, this difference is not noticeable (14 percent at T-intersections compared to 12 percent at four-legged intersections). A higher rate of single-vehicle crashes may be due to lack of conspicuity at the approaches of T-intersections in rural areas. Table 2 shows higher proportions of fatal/injury crashes (an additional 16 percent at four-legged sites compared to T-intersections). To a lesser extent, for two lanes intersecting four lanes, a higher proportion of combined fatal/injury crashes is revealed (9 percent higher for four-legged than T-intersections [table 3]). Offset T-intersections eliminate crossing maneuvers and reduce the number of potential conflicts.

Table 2. Level of Injury Comparison for Rural 2x2-Lane TWSC Intersections

<table>
<thead>
<tr>
<th>Injury Level</th>
<th>Washington State Data for 2x2 Lanes</th>
<th>Four-Legged (%)</th>
<th>T (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Incapacitating Injury=A</td>
<td></td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Non-Incapacitating=B</td>
<td></td>
<td>28</td>
<td>20</td>
</tr>
<tr>
<td>Possible Injury=C</td>
<td></td>
<td>24</td>
<td>19</td>
</tr>
<tr>
<td>Property Damage Only (PDO)</td>
<td></td>
<td>38</td>
<td>54</td>
</tr>
</tbody>
</table>

Table 3. Level of Injury Comparison for Rural 2x4-Lane TWSC Intersections

<table>
<thead>
<tr>
<th>Injury Level</th>
<th>California State Data for 2x4 Lanes</th>
<th>Four-Legged (%)</th>
<th>T (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Injury</td>
<td></td>
<td>59</td>
<td>51</td>
</tr>
<tr>
<td>Property Damage Only (PDO)</td>
<td></td>
<td>39</td>
<td>48</td>
</tr>
</tbody>
</table>

This study will focus on improving safety and operational performances of four-legged crossings by offsetting them and creating two offset T-intersections.

DESIGN AND SAFETY IMPLICATIONS
Most guidelines either recommend avoiding skewed intersections with angles less than 60° or providing the necessary sight distances and features (American Association of State Highway
A Policy on Geometric Design of Highways and Streets [Green Book]) (AASHTO, 1994). According to National Cooperative Highway Research Program (NCHRP) 279, special control features such as all-stop traffic signs and geometric improvements should be considered as well (Neuman, 1985). The most obvious improvements are the realignment of the approaches to achieve more perpendicular crossings. Another treatment is to install separator islands on the minor road; this can reduce angle collisions by 30 percent according to a French research report (Aubin et al., 1984). This cost-effective treatment can apply to cross and T-intersections. Angle collisions are 59 percent and 43 percent of the total crashes at cross and T TWSC intersections, respectively. Figure 1 is taken from the French guide on interurban intersections (SETRA, 1998). The findings resulted from a before/after study of 32 intersections on major rural roads in France (Aubin et al., 1984). Moreover, the effectiveness of these designs is greater when the entry path is curved or deflected in order to reduce speeds before the conflict area is reached, and when the curb of the separator island is traversable. Dimensions from the figure are tabulated in the referenced guide (SETRA, 1998, table 8).

![Figure 1. Design of separator islands at the minor approach for T- or cross intersections (SETRA, 1998).](image)

A report from Finland found that an obtuse angle formed with the minor road is conducive to safety where the left-turning traffic from the major road has more comfortable access onto the minor road with angles greater than 90° (figure 2) (Kulmala, 1995).
Vogt et al. have confirmed this theory in the development of crash models for four-legged rural intersections on two-lane roads (Vogt et al., 1998). Conversely, T-intersections with an obtuse angle from the minor road were found to have fewer crashes (Vogt et al., 1998). Considering that left-turn volumes were not variables in the crash models, explicit relationships between these volumes and the safety of obtuse angles could not be predicated. Therefore, a follow-up report by Harwood et al. provided crash modification factors for skewed intersections with negative safety effects, regardless of angle directions, citing lack of other evidence for the Finnish theory (Harwood et al., 2000):

\[
\text{AMF}_3 = \exp (0.0040 \text{ skew}) \text{ for three-legged intersections.}
\]

\[
\text{AMF}_4 = \exp (0.0054 \text{ skew}) \text{ for four-legged intersections.}
\]

Where skew = average intersection skew angle (degrees), expressed as the absolute value of the difference between 90° and the actual intersection angle.

For example, a 60° angle will have a skew equal to 30° and a crash modification factor equal to 1.18. In a before/after comparison, Yuan and Ivan evaluated nine sites whose skewed intersecting angles were realigned with other treatments as well (Yuan and Ivan, 2000). The results from this small sample size revealed a reduction in crashes ranging from 10 to 40 percent. However, the findings from the combined treatments cannot be directly attributed to angle realignment when the other treatments are adding signals and left-turn lanes. Moreover, run-off-road crashes increased at four of the nine sites.

A less common alternative is to offset the crossing to create two T-intersections as long as a minimum straight tangent of 46 m (150 ft) is provided before the intersection (Neuman, 1985). The Neuman NCHRP report noted that little through traffic is desirable when recommending offset T-intersections, although a maximum volume was not indicated.

**SAFETY ADVANTAGES**

**Non-Signalized Intersections**
This section applies to intersections with either skewed or perpendicular alignments. The safety benefits of converting four-legged (or cross) intersections to two offset T-intersections are explored and analyzed. Adding a signal to cross intersections (for safety-related warrants) is not a clear remedy for reducing crash frequencies. According to the Federal Highway
Administration’s (FHWA’s) Synthesis of Safety Research, many findings have indicated higher crash rates for rural intersections with signals (about 20 percent) because rear-end collision are expected to rise (Merton et al., 1982). However, angle collisions are reduced, as is the potential for severe collisions. Another remedy is to offset or stagger the two approaches of the cross intersection to separate and reduce conflict locations without requiring a signal when warrants are strictly safety-related. One of the very few papers on staggered intersections (Mahalel et al.) compared two types of offset (right to left [R-L] and left to right [L-R]) for cross intersections (figure 3) (Mahalel et al., 1986).

![Figure 3. Right-Left (R-L) and Left-Right (L-R) configurations.](image)

In this paper, many references were cited where injury crash reductions of 60 percent were reported (Mahalel et al., 1986). The L-R designs had greater reductions in injury crashes than the R-L designs (Mahalel et al., 1986). Nevertheless, Mahalel et al. favored the R-L layout mostly for operational reasons that create slightly less delay and higher capacity (Mahalel et al., 1986). Critical gaps for R-L designs are shorter than for crossing maneuvers. For 2x2-lane intersections, figure 4 shows a noticeable reduction in conflict locations (from 32 to 22). For two lanes intersecting four lanes, the conflict locations are reduced from 40 to 30.

![Figure 4. Potential conflict locations for 2x2-lane intersections.](image)
Providing a left-turn lane on the major road for an R-L design and a right-turn lane for an L-R design will mitigate the disadvantages of added interferences for through movements. Figure 5 from Mahalel et al. shows no interference when the distance is equal or less than 60 m for R-L and 80 m for L-R. At larger offsets, interferences are constant.

Figure 5. Potential vehicle interferences of traffic crossing the major road of 2x2-lane intersections when the major-road speed is 80 km/h (Mahalel et al., 1986).

Derived aggregate measures of crash rates (crashes per million entering vehicles) are 40 percent smaller for offset TWSC intersections in rural areas (Hanna et al., 1976). A similar reduction is noted between T- and cross intersections (table 4). A major difference may be due to a higher percentage (16 to 29 percent) of angle crashes at cross 2x2-lane intersections.

Table 4. Comparison of Crash Rates on Rural 2x2-Lane Intersections (Hanna et al., 1976)

<table>
<thead>
<tr>
<th>Intersection Design</th>
<th>Crashes per Million Entering Vehicles</th>
<th>Crash Reduction in Comparison to X</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1.27</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>0.79</td>
<td>38%</td>
</tr>
<tr>
<td>Y</td>
<td>1.04</td>
<td>18%</td>
</tr>
<tr>
<td>Offset</td>
<td>0.76</td>
<td>40%</td>
</tr>
</tbody>
</table>

Recent crash models are used in this study to confirm and illustrate the safety benefits of T- and cross intersections. The first comparison is derived from crash models for rural 2x2-lane cross and T-intersections (Vogt et al., 1985). These models are fitted from Minnesota data for 327 cross intersections and 389 T-intersections separately. Five years of crash data are modeled using negative binomial techniques to relate crashes to traffic volumes and intersection characteristics. The generalized linear form is as follows:

$$A = \text{Exp}(b_0 + \sum x_i b_i)$$

Where $b_j$ are coefficients of intersection variables $x_j$.

The negative binomial technique is a well-accepted approach that yields reliable data of mean expected performance. Figure 6 presents a crash comparison with 10 percent of the traffic flows from the minor roads. The assumption is that two isolated T-intersections are comparable to a cross intersection. Interferences can be minimized by providing the offset...
distances given below for the two defined geometries, R-L and L-R. According to the crash models, the reduction in injury crashes is higher (about 40 percent) than the reduction in total crashes (between 20 and 35 percent). The derived reduction in injury crashes is constant in relation to traffic volumes entering the intersections. A reduction in total crashes decreases and levels off at about 20 percent when the total entering average daily traffic (ADT) flow is 10,000. This higher reduction in injury crashes may be interpreted in light of table 2, which shows 16 percent fewer injuries than at cross intersections. When the percentage of traffic flows on the minor roads is increased, the expected reduction in crashes increases slightly. The assumptions for both models, the cross and T-intersections, are for level vertical alignments, without horizontal curvature, without right-turn lanes, and where the intersecting angles are perpendicular.

For TWSC intersections of 2x4-lane highways, the results are somewhat comparable to the 2x2-lane intersections in rural areas that reveal reductions in total and fatal/injury crashes. The reduction of crashes is diminished beyond 25,000 ADT to 20 percent for injury and 40 percent for total crashes. Unlike the above results, (for 2x2 lanes) total crashes were reduced more than fatal/injury crashes. With a 5-m- (16-ft-) wide median, turning vehicles are likely to make two consecutive left or crossing movements. Unfortunately, the impact of turning movements cannot be estimated from these crash models to help develop design guidelines for offset intersections. The major assumption of the crash model is that the four-lane State highway is divided.
Earlier crash models from Bauer et al. were also applied to compare T- and cross 2x2-lane TWSC intersections in rural areas. These sets of models also reveal a reduction in crashes, although smaller, from 10 to 20 percent for total crashes and 15 to 25 percent for injury crashes. However, the trend in relation to total entering ADT is increasing and then stabilizing at about 10,000 entering ADT.

**Signalized Intersections**

For signalized 2x2-lane urban intersections, a crash model for cross intersections is available from the Bauer et al. report (Bauer et al., 2000). Crash models for corresponding T-intersections are developed in this study from the same California database. Seven years of crash records and a sample of 45 intersections were modeled using the negative binomial technique stated above. The data were acquired from the Highway Safety Information System (HSIS) at FHWA’s Office of Research and Development. The model is fitted for total crashes in relation to entering ADT on the main road and entering ADT on the crossroad. A new aggregate model for signalized T-intersections is presented from an SAS analysis shown in table 5.

**Table 5. Negative Binomial Model for Urban Signalized T-Intersection With 2x2 Lanes**

<table>
<thead>
<tr>
<th>Variables (offset = number of years)</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>K = -4.9666</td>
<td>2.6773</td>
<td>0.0636</td>
</tr>
<tr>
<td>Log of ADT&lt;sub&gt;main&lt;/sub&gt;</td>
<td>a = 0.3008</td>
<td>0.2599</td>
<td>0.2470</td>
</tr>
<tr>
<td>Log of ADT&lt;sub&gt;cross&lt;/sub&gt;</td>
<td>B = 0.2867</td>
<td>0.0961</td>
<td>0.0029</td>
</tr>
<tr>
<td>Dispersion</td>
<td></td>
<td>0.5060</td>
<td></td>
</tr>
<tr>
<td>Scaled Deviance</td>
<td>1.18</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ A_T = N (ADT_{main})^a (ADT_{cross})^b \exp (k) \]

Where  
- \( A_T \) = expected number of crashes.  
- \( N \) = number of years.  
- \( ADT_{main} \) = entering ADT on the main road.  
- \( ADT_{cross} \) = entering ADT on the crossroad.  
- \( K \) = intercept.
For a ratio of 60 percent to 40 percent main to crossroad ADT, figure 8 shows an expected reduction in crashes beyond 2,500 total entering ADT. The reduction rises and levels off at about 25 percent (18,000 ADT). Similar to the TWSC intersections above, the assumption is that interferences between the two T-intersections do not negatively impact safety. The reliability of this comparison is not specific to geometric features or signal types or settings. Although the new model fit is not strong and the coefficient of the main-road ADT is not significant, the estimation is a conservative mean safety performance. In general, the model is overpredicting in comparison to actual data. The majority of the sampled intersections include left-turn lanes with signals that are fully actuated.

![Figure 8. Crash reduction for urban 2x2-lane signalized intersections with 60:40 main to crossroad ADT.](image)

**COMPARISON OF TRAFFIC PERFORMANCE**

According to Mahalel et al. (1986), on rural 2x2-lane TWSC intersections, the capacity of minor-road approaches is higher for R-L offset T than for L-R and cross intersections. A higher capacity is estimated to be approximately 200 veh/h. Nevertheless, left-turn capacity from the major road is slightly (30 to 100 veh/h) higher for cross intersections. Consequently, the R-L design causes less delay (5 to 20 s/veh) than cross and L-R designs. For signalized 2x2-lane intersections, an analysis is conducted using CORSIM to compare cross and offset T for a case study. Similar geometries and dimensions were assumed for typical cross and L-R offset designs where the left-turn lanes are 61 m (200 ft) long on the major-road approaches. Right-turn lanes on the major-road approaches are 31 m (100 ft) long. On the minor roads of the typical cross intersection, left-turn lanes are 31 m (100 ft) long, and no right-turn lanes are provided. On the minor roads of the offset T, neither right- nor left-turn lanes are provided, because equal access (to left and right turns) is given on a single phase. Optimum signal settings were obtained from TRANSYT-7F for both types of designs. TRANSYT-7F provided optimum cycle length, phase splits, and offset between the two signals of the offset T. Table 6 provides all scenarios used in the analysis where opposing flows are assumed to be balanced and all left-turn proportions are constant (15 percent) on all approaches. The ratios of minor to major road volumes range mostly from 30:70 to 40:60. The CORSIM results of the experiment are shown in figure 9 for a simulation period of 20 min and uniform traffic flow arrivals. Total network travel time is used as a uniform measure of effectiveness for the two typical designs. The offset between the two T-intersections is 61 m (200 ft) long and the network length is equivalent to the typical cross intersection. Total network travel time is an adequate measure because through movement vehicles on the minor road will have to travel...
longer distances on an offset T design than a cross intersection. With pre-timed signal settings, coordinated signals will reduce the number of phases by one for the offset T design. Thus, longer effective green time creates less delay and travel time for the offset T. At low to medium entering flows, the two typical designs are somewhat comparable up to about 2,300 veh/h. A more significant savings in travel time of 5 to 20 s/veh is shown beyond 2,300 veh/h. The findings from a typical R-L design indicate that this treatment could be detrimental to traffic operations when the offset between the two T-intersections is not long. Moreover, the cost of construction to add long left-turn lanes between the two intersections could be prohibitive. Table 6 shows a consistently higher percentage of stopped vehicles at the offset T, which might have safety implications. Conversely, the average stop times and delay times per vehicle are mostly shorter for the typical offset T design.

<table>
<thead>
<tr>
<th>Total</th>
<th>Major Rd</th>
<th>Minor Rd</th>
<th>Stop (%)</th>
<th>Stop Time (secs/veh)</th>
<th>Delay Time (secs/veh)</th>
<th>Stop (%)</th>
<th>Stop Time (secs/veh)</th>
<th>Delay Time (secs/veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>400</td>
<td>400</td>
<td>75</td>
<td>15.6</td>
<td>23.4</td>
<td>107.2</td>
<td>12</td>
<td>22.8</td>
</tr>
<tr>
<td>1200</td>
<td>800</td>
<td>400</td>
<td>75.5</td>
<td>15</td>
<td>24</td>
<td>96.5</td>
<td>13.2</td>
<td>23.4</td>
</tr>
<tr>
<td>1500</td>
<td>900</td>
<td>600</td>
<td>78.7</td>
<td>16.2</td>
<td>25.8</td>
<td>116</td>
<td>17.4</td>
<td>25.2</td>
</tr>
<tr>
<td>1800</td>
<td>1200</td>
<td>600</td>
<td>78</td>
<td>16.2</td>
<td>27</td>
<td>109.2</td>
<td>14.4</td>
<td>28.2</td>
</tr>
<tr>
<td>2000</td>
<td>1400</td>
<td>600</td>
<td>83.3</td>
<td>18.6</td>
<td>31.2</td>
<td>96.5</td>
<td>12.6</td>
<td>22.2</td>
</tr>
<tr>
<td>2300</td>
<td>1400</td>
<td>900</td>
<td>84</td>
<td>19.8</td>
<td>31.2</td>
<td>114</td>
<td>18.6</td>
<td>23.4</td>
</tr>
<tr>
<td>2400</td>
<td>1800</td>
<td>600</td>
<td>83.3</td>
<td>22.8</td>
<td>37.8</td>
<td>116.4</td>
<td>18.6</td>
<td>34.2</td>
</tr>
<tr>
<td>2500</td>
<td>1600</td>
<td>900</td>
<td>88</td>
<td>27</td>
<td>42</td>
<td>115.6</td>
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<tr>
<td>2700</td>
<td>1800</td>
<td>900</td>
<td>88.8</td>
<td>34.8</td>
<td>55.2</td>
<td>109.3</td>
<td>21</td>
<td>37.2</td>
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<tr>
<td>2900</td>
<td>2000</td>
<td>900</td>
<td>92.7</td>
<td>46.8</td>
<td>77.4</td>
<td>115.7</td>
<td>47.4</td>
<td>46.8</td>
</tr>
</tbody>
</table>

Figure 9. Network travel time for cross intersections and offset T-intersections.

GUIDELINES FOR NON-SIGNALIZED INTERSECTION OFFSETS

The derived guidelines provide maximum offsets between offset T-intersections that minimize the interference of the major-road vehicle with the slow-moving or accelerating vehicle from the minor road. Major assumptions are comparable to those in the Mahalel et al. report. A minor-road driver will not accept headways smaller than the critical gap. Much larger headways than the critical gap will not create interferences when taken by a minor-road driver because he/she will not be reached by the major-road driver. The most critical movements occur when the minor road driver accepts a critical gap. The major road speed is assumed constant as the measured operating speed. The zero reference point is considered at
the beginning of the lane merge on the major road, where the minor road vehicle merges onto the major road. \( T \) is the time needed for the major-road vehicle to reach the accelerating vehicle from the minor road that starts from a stopped position. The travel distance by the major-road vehicle is \( D \):

\[
D = V_M (T - t_c)
\]

Where \( V_M \) = operating speed on the major-road.

\( T \) = time of travel when the major- following the minor-road vehicles meet, assuming the major-road vehicle does not decelerate.

\( t_c \) = critical gap of 6.5 s for right-turning passenger cars on two-lane roads.

= critical gap of 7.5 s for left-turning passenger cars on two-lane roads.

= critical gap of 7 s for right-turning passenger cars on four-lane roads.

= critical gap of 8 s for left-turning passenger cars on four-lane roads.

These critical gap values extracted from NCHRP Report 383 (Harwood et al.) have been adopted for use in the 2001 AASHTO Green Book. The distance in the above equation is equivalent to the distance traveled by the accelerating vehicle from the minor road, measured on the major road only. The second term on the left side of the equation below subtracts the horizontal arc that is the distance of a stopped vehicle to turn onto the major road.

\[
\frac{1}{2} a T^2 - d = V_M (T - t_c)
\]

\( a \approx 5 \text{ ft/s}^2 \), which is the derived approximation of an assumed constant acceleration rate from the AASHTO Green Book, 1994, figure IX-33 for passenger cars.

\( d \) = horizontal arc of a minor road vehicle turning right onto a two-lane major road plus vehicle length (8 +15 ft) = 23 ft.

= horizontal arc of a minor road vehicle turning left onto a two-lane road plus vehicle length (24 +15 ft) = 39 ft.

= horizontal arc of a minor road vehicle turning right onto the farthest lane of a four-lane road plus vehicle length (24 +15 ft) = 39 ft.

= horizontal arc of a minor road vehicle turning left onto an undivided four-lane road plus vehicle length (42 +15 ft) = 57 ft.

= horizontal arc of a minor road vehicle turning left from the median onto the farthest lane of a divided four-lane road plus vehicle length (24 +15 ft) = 39 ft.

Tables 7 and 8 provide derived distances \( D \) or offsets (from the above equation after solving for \( T \)) for various major-road operating speeds below which few or no interferences are possible. For lower speeds and those missing from the table, no interference is possible because the minor-road vehicle is capable of reaching major-road speeds without causing the major-road vehicle to decelerate. Several guideline interpretations apply to tables 7 and 8. For R-L offset \( T \) designs, a left-turn storage lane will help in removing the minor-road turning vehicle from the mainstream. The recommendations below apply to R-L designs only:

- ✓ When left-turn lanes for deceleration and storage are provided back-to-back, the indicated offset in figure 10 should be less than or equal to the given maximum offset in tables 7 and 8.
- ✓ If a left-turn pocket is not provided (e.g., under very low-volume conditions), the offset is between the two intersections.
When left-turn lanes need to be longer than the given distances, parallel left-turn lanes could be used, where the offset from one intersection to the start of the left-turn lane should not exceed the distances in tables 7 and 8.

Similar to R-L, L-R designs with right-turn pockets will remove the minor-road turning vehicles from the mainstream.

When right-turn lanes are provided, the distance from one intersection to the start of this lane should be less than or equal to the distances in tables 7 and 8.

If a right-turn pocket is not provided, the offset between the two intersections should not exceed the corresponding distances in tables 7 and 8.

Offsets for L-R designs in table 8 apply to undivided four-lane major roads. When a median is present, drivers making left-turns are more likely to take refuge in the median and merge with major road traffic on the farthest lane. Table 9 provides offsets for L-R designs. However, offsets for R-L designs are the same as in Table 8.

Table 7. Maximum Distances to Minimize Interferences for Two-Lane Roads

<table>
<thead>
<tr>
<th>Major Road Speed</th>
<th>Maximum Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>mph</td>
<td>kph</td>
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<tr>
<td>45</td>
<td>72</td>
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<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>60</td>
<td>96</td>
</tr>
<tr>
<td>65</td>
<td>104</td>
</tr>
<tr>
<td>70</td>
<td>112</td>
</tr>
</tbody>
</table>

Table 8. Maximum Distances to Minimize Interferences for Undivided Four-Lane Roads

<table>
<thead>
<tr>
<th>Major Road Speed</th>
<th>Maximum Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>mph</td>
<td>kph</td>
</tr>
<tr>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>60</td>
<td>96</td>
</tr>
<tr>
<td>65</td>
<td>104</td>
</tr>
<tr>
<td>70</td>
<td>112</td>
</tr>
</tbody>
</table>

Table 9. Maximum Distances to Minimize Interferences for Divided Four-Lane Roads

<table>
<thead>
<tr>
<th>Major Road Speed</th>
<th>Maximum Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>mph</td>
<td>kph</td>
</tr>
<tr>
<td>45</td>
<td>72</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>60</td>
<td>96</td>
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<tr>
<td>65</td>
<td>104</td>
</tr>
<tr>
<td>70</td>
<td>112</td>
</tr>
</tbody>
</table>
CONCLUSIONS AND RECOMMENDATIONS

- If angle collisions are abnormally high, one of the most economical remedies is to provide separator islands on the minor approaches shown in figure 2. A deflection of the entry path will force minor-road drivers to slow down and become more responsive to their environment. This treatment is most effective in rural areas for 2x2- and 2x4-lane intersections.

- For 2x2-lane TWSC rural intersections, the application of offset T-intersections is a treatment option to improve safety at high hazard locations. Derived benefits apply to both perpendicular and skewed crossings.

- On an aggregate level, the expected benefit of converting a cross intersection to an offset T-intersection is a reduction in total crashes of 20 to 30 percent for rural 2x2-lane TWSC intersections. A reduction in fatal/injury crashes is expected to be approximately 40 percent.

- According to the trend shown in figure 6, at flows greater than 10,000 entering ADT with a 10-percent traffic flow on the minor road, a conversion to offset T-intersections may not be cost-effective. At higher flows, warrants 1 or 2 for signal installation are likely to be met.

- For 2x4-lane TWSC intersections in rural areas, converting a cross intersection to an offset T-intersection is a viable option that is expected to reduce crashes considerably at low to medium flows up to about 25,000 ADT. Similarly, the warrant for installing signals is likely to be met at the upper limits. Nevertheless, a single-volume warrant may not always be a satisfactory reason for signalization. The expected reduction in total crashes ranges from about 60 to 40 percent for divided four-lane highways with design speeds greater than 80 km/h (50 mi/h).

- In urban environments, a high hazard or congested 2x2-lane signalized intersection could benefit from a conversion to two offset T-intersections in safety and traffic operations when the design is L-R only. The derived advantages are an expected 20-percent reduction in total crashes at higher ADTs and 5 to 20 s/veh less travel time. In...
tight urban environments, this conversion is possible in a grid network by closing some access and/or rerouting traffic.

A future research topic is to determine guidelines on the offsets between two signalized T-intersections with 2x2-lane and 2x4-lane intersections.
REFERENCES


THE POLICY OF STATE REGULATION IN THE SUB SYSTEM ‘STATE CONTROL OF THE VEHICLE CONDITION’

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It’s obvious that the problems of the safety of this complex in Russia are especially actual in all the three components. But our research is limited only by active safety.

Let me combine my three reports that were announced into one and give you their theses as they have been published.

1 Both the construction and operation of national vehicles are characterised by much lower safety level. Their construction misses a number of modern systems like ABS, anti-skid system, running dynamics control system and impact preventing automated system and methods of controlling the safety of vehicles in operation are ineffective under the modern conditions of transient economics.

In this connection, we first of all analyzed, processed and compared with Russian normative documents (State Standard Specifications, Standard Specifications of Branches of Industry and directions) about fifty regulations of the European Economic Commission of the United Nations devoted to active safety.

The results of this work are now being published in three parts “Running characteristics, stability and informativity of vehicles and road safety”.

2 Then we singled out the direction dealing with ensuring safe operation which was examined in the aspect concerning the ensuring of vehicle safe operation we’ll consider it, bearing in mind the main negative tendencies – the decrease of professional skills in automobile industry, insufficient information about road safety and the decrease of the motor car technical service potential.

We consider that the special problem is the above mentioned control in the "niche" of category M₁ vehicles and partially (full weight up to 3,5 tons) M₂ and N₂, the fleet of which provides up to 80 per cent of city transportation and is the reason of up to 85 per cent of the road accidents in the cities. The problem is even more serious because of an extremely small fleet of vehicles belonging to licensed personnel dealing with transportation of goods as, according to Russian Transport Inspection (RTI), 88 per cent of them have from 1 up to 5 and only 1,4 per cent have more than 50 vehicles.

The main trend of this policy in Russia is control of the vehicle technical condition on three hierarchical levels: 1 - regular production control (self-testing (control) at controlling and technical departments of enterprises); 2 - branch inspection control (RTI - through licensing and signing the agreement with production and technical base of the service of motor cars); 3 - state inspection control (State Road Safety Inspection – through state technical examination and other forms). For the mentioned "niche" of vehicles – the 1-st level misses, the 2-nd is ineffective, and 3-rd is insufficient, universal compulsory requirements not being met at all levels. The USA, for example, practise selective instrumental control that keeps traffic participants in "tension".

The second trend is the improvement at federal level of the system of car service certification including its technical equipment and periodical inspection control of production and technical base of car-service enterprises. The best example is Japan where it is common practice to change units and parts effecting road safety the determined life-time of which is over (as in aviation).

The third trend, as in Germany, maybe the development at federal level of the system of obligatory insurance of both vehicles themselves and the process of their running that economically stimulates renovation of the car fleet.

Thus, the essence of this policy is optimum combination of the mentioned trends and search of new solutions with regard for foreign experience.

3 It is obvious that a change in vehicle technical condition during its service defined by the efficiency of its units and systems results in the reduction of the main parameters of active safety.

In this connection it is important to carry out a theoretical and experimental research of the degree of this influence and permissible bounds of the change beyond which road safety is considerably reduced and possibility of road accidents increases.

Taking into account modern vehicle constructions, first of all the system controlling the dynamics of running on the basis of anti-lock braking system and automatic system of impact preventing, we deal with the less known, compared with dynamic quality, aggregate parameters of active safety – stability, controllability, turnability and running smoothness.

These aggregate parameters allow to investigate permissible (according to road safety regulations) limits of change of a technical condition of steering, front steering axle, suspension and tyres.

Theoretical research includes the development of four mathematical models steering and front steering axle; suspension and tyres; a vehicle on the dynamic all-wheel supported stand with rotating drums, which records the geometry of chassis in the position of minimum resistance to movement and also the running of biaxial vehicle in three modes.

The models allow to carry out investigations in the following modes of movement: conditionally rectilinear, curvilinear, entering the turn, coming out of the turn, obstacle detour and in these combinations.

In conclusion a number of basic indications of reducing road safety are estimated: “wander”, skid, side slip, dumping, changing of course and drift angles and others including tiredness of the driver through their main parameters.

The last two trends are the object of my research work for Doctor’s degree and have not been published yet.
Differences in Traffic Signs’ Recognition between Drivers of Different Nations

By

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Dept. of Civil & Arch. Eng., University of Bahrain, Bahrain

Abstract

Drivers encounter tens of signs in their daily trips. While many signs are well recognized by the drivers, many others are not. This study examines drivers’ identification of 28 warning and regulatory signs. The identification rate was standardized as per sign exposure rate. Differences between nationalities are then tested. Questionnaires included these signs were distributed to 9000 drivers in Bahrain, Kuwait, Oman, Qatar, and United Arab Emirates. Over 4850 responded back (54%). The questionnaire illustrated the tested signs in color along with four selection choices. In order to have just comparisons between the drivers of the various nationalities, their educational background is controlled. Three best-identified signs by the drivers included those indicating slippery road, closed to motor vehicles and road narrows from both sides. The three least identified are those indicating no waiting, turn left ahead and turn left. The findings also showed the existence of functional problems in many regulatory signs. In fact, only one third of the signs are equally understood by Arab, Asian and Westerner drivers. The drivers poorly identified most of the signs included in this group. Furthermore, both Arab and Asian drivers identified another one third of the signs significantly less than Westerners. The signs in this group are generally well identified by the drivers. Regulatory signs indicating symbolic pictures caused greater comprehension difficulties to the drivers
in this group. Finally, two third of the signs are poorly identified by Arab drivers compared with westerners. Warning signs are over-presented in this group.

Key words: warning signs, regulatory signs, understanding, identifying, sign exposure rate, Arabs, Asians, Americans and Europeans.

INTRODUCTION

Posted road traffic signs are the most commonly used traffic control devices. Their main function is to provide the road users, specially the drivers, with the important navigational messages. They serve other needs, as well, as will follow. However, questions such as: does better understanding of such signs mean less accident involvement; is there any relationship between drivers’ understanding of posted signs and their speed limit citations; does understanding of such signs increase with driving experience and how is the drivers seat belt usage related to their knowledge of posted signs, are investigated in this study.

Many accidents occur because the driver is suddenly confronted by the unexpected. The driver should, therefore, be warned by means of traffic signs, as much as possible, for any abnormal driving situations ahead (Pignataro, 1973). These signs convey messages in terms of words or symbols. Signs are, therefore, essential where special regulations apply at specific places or at specific times, where hazards are not self-evident. According to US Department of Transportation (1989), improvement in traffic signs at intersections lead to 34 % reduction in fatal accidents and 93 % in injury related accidents in United States. In fact the effectiveness, as per Benefit / Cost ratio, appears to be the highest compared with traffic channalization facilities,
sight distance, markings, illumination and traffic signal improvement. The improvements in the posted signs include the location and the illumination.

Although traffic signs are very uniform all over the world, many countries have issued their own sign manuals. Traffic signs, however, are most effective when they satisfy the following fundamentals: fulfill a need, command attention, convey a clear and simple meaning, command respect of the road users and give adequate time for proper response (Institute of Transportation Engineers, 1992). The subject of this investigation is related to the third fundamental parameter, namely conveying a clear meaning to the users.

One of the earliest studies on posted signs was that of Riegelmeier (1942) on rehabilitation of signs. A wide range of techniques, in fact, evaluated roadways posted signs. In the forties and early fifties many of the researches in this field were technical related studies, such as those related to impact assessment, cost estimation, accident evaluation and illumination effectiveness. In the early sixties researchers started to give more weight to human related studies, particularly the motorists behavior. Hakkinen (1965), for example, directly assessed the influence of road signs on drivers’ behavior by measuring their sign recall with such measures as speed reduction. Other investigators measured the visibility of the signs and drivers’ recognition at different approaching speeds, taking into consideration different social and psychological backgrounds of the drivers (Johansson et al., 1966 and 1970). Others (Summala and Naatanen, 1974; Drory et. al, 1982, and Ells and Dewar 1979) tested the effect of illumination and brightness of the signs on both users response and drivers’ reaction time. However, studies of drivers’ characteristics, particularly the
safety related ones, with respect to their understanding of the informational values of
the signs and how well do such signs guide drivers are not, yet, extensively covered.

Jabbar and Naqvi (1992) found that drivers commit significant errors in detecting
symbolic signs compared to alphanumeric ones. Therefore, to incorporate users’
comprehension, modifications to certain signs might be necessary. Alphanumeric
signs are better when compared to symbolic ones, so are warning signs compared to
regulatory signs (Dewar et al., 1976) since the drivers regard them to be more serious.
However, this was not true when “head room hazard” sign was considered. Goler
(1980) found that 21% of the long truck drivers did not understand such signs.
Laboratory tests showed that drivers perceive the word “danger” to indicate the
highest level of alert compared to “caution” and “warning”. When such words were
posted with different backgrounds, the greatest impact was found for “danger” with a
red background (Chapanis, 1994).

Fisher (1992) measured the informational value of road traffic sings by questioning
drivers at roadblocks. He found drivers’ memory for road signs to be typically poor.
Further, he strongly recommended not assessing the effectiveness of road signs in
terms of driver’s recall. In fact, they should be assessed in terms of their ability to
sensitize the driver to hazards, regardless of those who ignore such signs. However,
Book and Bergstrom (1993) tested the correlation between amount of reduction in
frequency of sign occurrence and the complete elimination of sign. He found a strong
correlation between the two, but for the higher experience group of drivers only.
Otani et al. (1992) found that drivers over 60 years old indicate higher risk in ignoring the warning signs. This may be indicative of some sort of overconfidence in them. Richard and Heathington (1988) made a survey of motorists’ comprehension of railroad grade crossing traffic control devices (signs and signals). Their results indicated that very young drivers (under 19 years) and elderly drivers (over 54 years) face difficulties in understanding and recognizing such devices. Significant differences between novice and experienced drivers were also observed. Drivers who disregard, even plausible, speed limits face more serious accidents and more traffic violations than those who observe the limits. Typical observers of speed limits are females aged between 40 and 60 years. Typical non-observers are males, between 25 and 40 years (Schmidt, 1982). Factors associated with compliance and noncompliance with traffic regulations, as safe driving practice and observation of regulatory signs, was investigated by Hofner (1982). Their results contradicted at least age wise, with Otani. al (1982). Hofner found compliers to be conscious (safety wise), either under 30 years or over 60 years old, drove medium power cars, had less driving experience and fewer traffic fines than non-compliers. Typical non-compliers who tended to take risks, were between 45 and 55 years, were executives or self employed and drove high power cars. Both groups, however, provided similar ratings for different traffic violations.

AIMS

This study examines drivers’ understanding of 28 different regulatory and warning signs. The understanding score is standardized considering the exposure rate of each sign. Each sign is analyzed individually. Furthermore, the study examines the following hypothesis: Arab and Asian drivers poorly identify many signs when
compared with Europeans and Americans. In fact, problems in understanding traffic signs particularly by non Anglo drivers, i.e. those who do not speak English as their primary language as Hispanic, and African American drivers were observed by Hawkins, et. al (1993).

Furthermore, many studies reported that road sign system does not fulfil its intended and assumed function in a satisfactory way, e.g. Johansson & Rumar (1966), Fisher (1992), and Al-Madani (2001). Summala & Hietamaki (1984) referred the defective function of traffic sign system to mainly motivational factors.

**METHODOLOGY**

The method adopted here involved questionnaires to be filled by the drivers who were selected randomly based on stratified random sampling technique (Stopher et. al 1979; Steven, 1992; and Ortuzar et. al, 1996). The stratification was based on occupation. The proportion of the various occupations, country wise, was first obtained. Accordingly, the questionnaires were distributed to the various related institutions. The various occupations were classified into twelve groups.

The questionnaire involved short-answers and multiple-choice questions. The short-answer questions were designed to identify the drivers’ traffic and safety related characteristics satisfying the above goals and the multiple-choice questions evaluated drivers’ comprehension of posted traffic signs. The questionnaire included 28 multiple-choice questions on different posted signs, printed in colors, both in Arabic and English; 18 on regulatory signs, e.g. speed, weight and height limits; parking, turning and overtaking prohibitions; and directional movements, and 10 on warning signs, e.g. staggered junction, road narrowing and splitting, turnings and diversions.
Language and educational experts approved the suitability of the questionnaire, before being distributed. Drivers’ average identification of each sign is first determined in descending order. The average of each sign is then divided by its exposure rate. The exposure rate of the sign is determined by their postage frequency per 1000 km. Since such data were not available in the related departments; 964 kilometers of different categories of roads were carefully selected and examined, in Bahrain and Kuwait, for the exposure rate measurement of each considered sign. Multiple usage of any sign, in any one particular site, was considered as single usage. In order to compare Arab and Asian drivers with Westerners on equal basis, only those holding B.Sc. degrees or over, was considered here since non Arab drivers in the region are well educated. It is also important to mention that drivers from the considered nationalities are randomly selected within the Gulf Cooperation Council Countries, not from their own countries. This was because of time and financial constraints. This may limit the application of the results.

Analysis of variance, using Scheffe’s technique, was then performed in order to test the hypotheses. The procedure evaluated the significance of the difference at 0.05 level, between the score of the drivers in the various groups.

**DATA COLLECTION**

The questionnaire was distributed to 9000 drivers in Bahrain, Kuwait, Oman, Qatar, and United Arab Emirates. Over 4850 responded back (Al-Madani et. al, 1995 and 1996). A response rate of 54 % was achieved. This represented over 0.05 percent of the total number of vehicles registered in each state. This is equivalent to over one million questionnaires that would be required for the United States (Economic Commission for Europe, 1994) as per this response rate. Both the response and the
response rate are thought to be sufficient, as many studies (e.g. Dean, 1981 and Steven, 1992) consider samples as high as 500 to be representative for any large populations if properly distributed according to a known statistical technique. Moreover, Hofner (1982), for example, ended up with 39% response rate when he investigated drivers’ compliance and noncompliance with regulatory signs. However, Schmidt (1982) successfully ended up with 67%.

All the necessary data are from drivers self response to the questionnaires. The reduced data were analyzed using statistical software called Statistical Package for Social Sciences (SPSS, 1996).

RESULTS AND DISCUSSIONS

The top seven signs best identified by the drivers, regardless of sign exposure rates, found to be those indicating following (Table 1): no right turn (92%), dual carriage with three lanes- the right hand lane is closed (86.0%), no U turn (85.9%), slippery road (84.2%), road narrows on left ahead (80.2%), turn left ahead (77.9%) and turn left no waiting (77.3). Similarly, signs least understood by the drivers are as follows: end of prohibition of overtaking (35.2%), mini roundabout (35.0%), end of prohibition of goods’ vehicles (32.6%), no pedestrian are allowed to pass (30.3%), diversion to opposite (29.1%), staggered junctions (21.4%), and vehicles may pass on either way (16.3%). It is worth noting here, that the tested signs included two regulatory signs indicating “end of prohibition” order. Both proved to be among the least understood order signs by the drivers. Nevertheless, when drivers’ identification
of signs are standardized as per sign exposure rate, in 1000 kilometer of road links, the above order completely changes (Table 2). In this case the signs best understood by the drivers are those indicating the following (in order): slippery road, closed to motor vehicles, road narrows on both sides, dual carriage way ends, hump bridge ahead, diversion to opposite, and maximum axle weight limit. The least seven are those indicating the following: no waiting, turn left ahead, turn left, keep right, other danger plate indicates nature of danger, traffic merges from left, and maximum speed limit. From the above, one may clearly observe existence of understanding problems with some of the regulatory signs. Although 18 signs out of the 28 tested ones were regulatory signs, only two out of the seven best identified signs were regulatory signs. Moreover, out of seven least identified signs five were regulatory signs. This indicates that the drivers comprehend warning signs better than regulatory ones. Furthermore, signs regulating traffic path, i.e. those indicating white arrows on a blue backgrounds, are not functioning as intended or assumed since three out of the four tested signs were among the least understood by the drivers.

**Signs by nationalities**

Analysis of variance is performed to test the significance of the difference between the following nationality groups of drivers: Arab, Asian, European and American (Westerners) and others (Africans and Australians). The result of the analysis can be grouped into three categories. The first includes signs equally understood by Arab, Asian and Westerner drivers. The second includes signs poorly understood by Arab and Asian drivers compared with Westerners. The third includes signs poorly understood by Arab drivers, compared with Westerners.
Signs equally understood by Arab, Asian & Westerner drivers:

The above three nationality groups (Table 2) identify only one third of the tested signs equally. Out of nine signs resulted here only two were warning signs. The remaining seven were regulatory ones. In fact, four of these signs were among the least eight understood, as mentioned earlier. These include regulatory signs indicating turn left, speed limit, no waiting, and no entry for vehicular traffic. The remaining three regulatory signs were among the thirteen signs least understood by the drivers. The two warning signs appeared here, (Table 2) those indicating dual carriageway way with three lanes-the right hand lane is closed and road narrows on left ahead, were slightly better identified by the drivers than the regulatory ones. Nevertheless, they still were among the least sixteen understood signs. It is also worth mentioning that only one sign carrying a pictorial symbol, i.e. symbol picture of a vehicle, bridge, pedestrian, or so, appeared among the nine signs equally understood by the drivers of the above nationality groups, though seven such signs were tested here. This indicates under-presentation of such signs within this group. The regulatory signs equally understood by the drivers were mostly indicating prohibition action, as entry, turning, parking, waiting or passage.

The above discussion clearly confirms the existence of functional the problems in drivers’ understanding of regulatory signs, compared with warning signs, considering Arabs, Asians, and Europeans and Americans. Furthermore, the drivers generally poorly comprehend signs equally understood by the drivers in these nationality groups.
Signs poorly understood by Arab and Asian drivers compared with Europeans and Americans:

As shown in Table 3, eight signs out of the 28 analyzed signs appeared to be poorly understood by both Arab and Asian drivers when compared with Westerners. Over half of these signs were among the best ten understood signs by the drivers. This indicates that although many signs are well comprehended by the western drivers, Arab and Asian drivers significantly less comprehend them. In fact, the western drivers identified almost one third of the tested signs significantly better than the other two groups mentioned earlier. Moreover, since three out of eight signs (38%) appeared here are warning signs, the other five are regulatory ones, both warning and regulatory signs are well presented here when compared with the warning signs considered among the total tested signs. The percent of the warning signs was 36%. In contrary to this, symbolic pictorial signs are over presented here, since 38% of the signs shown here are symbolic pictorial ones compared with 25% in the total number of signs considered here. The four symbolic pictorial signs, which showed the westerner drivers to be significantly better than Arab and Asians, are these indicating.

Signs poorly understood by Arab drivers compared with European and Americans:

Beside the eight signs mentioned in the previous section, there are still further eleven signs, which are significantly less well identified by Arab drivers compared with Westerners. In total these sum up to be two third of the total tested signs, which indicate the inadequacy of such signs to the Arabian drivers. Furthermore, they included all the eleven signs best understood by all the drivers. While warning signs included in the tested sample were only 36%, they were 42% in the group of signs...
that were significantly less well understood by Arab drivers compared with westerners. This indicates over presentation of such signs in this group. In other words, warning signs are more difficult to be comprehended by Arab drivers compared with westerners. Over half of these signs were among the best ten understood signs by the drivers.

The above findings indicate that although many signs are well comprehended by the western drivers’ they are significantly less well comprehended by Arab and Asian drivers. In fact, almost one third of the tested signs were identified by the western drivers significantly better than both Arab and Asian drivers. Since here

**General Discussion:**

America and ECU countries have established means of learning traffic signs long back compared with many other countries. As a result, their drivers have better comprehension skills towards posted signs when compared with others. The findings discussed earlier confirmed such a statement. To reduce such differences in comprehension of signs and to improve the signing skills of the drivers form different nations; the manufacturers, designers, and researchers in the field of traffic signs, who are mostly form Europe and America, should restudy the design of many of the existing signs. This particularly true for those signs which are significantly less understood by other nationalities. An improved signing system which suites the need of the drivers in less developed countries is necessary. In other words the improved signing system should convey regulatory and warning information in a way correctly comprehended by the drivers in developing and under developed countries. On the other hand, authorities in the latter countries should improve their traffic education system in order to raise the drivers’ comprehension skills of traffic signs.
CONCLUSIONS AND RECOMMENDATIONS

1. Top three best-identified signs by the drivers are those indicating “slippery road”, “closed to motor vehicles”, and “road narrows from both sides”. The least three are those indicating “no waiting”, “turn left ahead”, and “turn left”.

2. The drivers identify the warning signs better than regulatory ones.

3. Functional problems clearly exist in regulatory signs indicating direction of traffic, i.e. those with white arrows on blue backgrounds.

4. Only one third of the signs are equally understood by Arab, Asian and European and American drivers. In general, signs equally understood by these nationalities carried the following characteristics:
   i. They are poorly identified by the drivers.
   ii. Warning signs are underrepresented.
   iii. Regulatory signs within this group, which are over presented, are mostly those indicating prohibition action as entry, turning, parking, waiting, or pedestrian passage.

5. Arab and Asian drivers poorly understand one third of the existing signing system when compared with Europeans and Americans. These signs have the following characteristics:
   i. They are generally well comprehended by the drivers.
   ii. Regulatory and warning signs are equally presented.
   iii. Regulatory signs indicating symbolic pictures causes greater comprehension difficulties to the Arab and Asian drivers, compared with the westerners, when compared with other regulatory signs.

6. Two third of the signs are poorly comprehended by Arab drivers compared with Europeans and American.
7. Warning signs are more difficult to be comprehended by Arab than regulatory ones when compared with Europeans and Americans.

REFERENCES


Al-Madani, H.M.N. and Al-Sada I., University of Bahrain and Swedish Road and Transport Research Institute, Safety on Roads an International Conference (SORIC’98), Bahrain; 1998.


SPSS. 6.1 Syntax Reference Guide. SPSS Inc., USA, 1996.


Table 1 Exposure rate of signs, drivers’ identification of signs and drivers’ identification per exposure rates

<table>
<thead>
<tr>
<th>Sign no. as appeared in the questionnaire</th>
<th>Title of the sign</th>
<th>Sign exposure rate/1000 km</th>
<th>Drivers’ correct Identification of sign (%)</th>
<th>Drivers’ correct Identification of sign (%)/1000 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Axle weight limit</td>
<td>1.5</td>
<td>38.3</td>
<td>25.5</td>
</tr>
<tr>
<td>2</td>
<td>Mini roundabout</td>
<td>46</td>
<td>35.0</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>No pedestrians are allowed to pass</td>
<td>9</td>
<td>30.3</td>
<td>3.4</td>
</tr>
<tr>
<td>4</td>
<td>Turn left</td>
<td>141</td>
<td>73.6</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>Maximum height limit</td>
<td>92</td>
<td>74.1</td>
<td>0.8</td>
</tr>
<tr>
<td>6</td>
<td>Maximum speed limit</td>
<td>688</td>
<td>77.3</td>
<td>0.1</td>
</tr>
<tr>
<td>7</td>
<td>No stopping</td>
<td>54</td>
<td>36.6</td>
<td>0.7</td>
</tr>
<tr>
<td>8</td>
<td>No right turn</td>
<td>51</td>
<td>92.2</td>
<td>1.8</td>
</tr>
<tr>
<td>9</td>
<td>No waiting</td>
<td>11</td>
<td>41.0</td>
<td>3.7</td>
</tr>
<tr>
<td>10</td>
<td>End of prohibition of overtaking</td>
<td>2</td>
<td>47.5</td>
<td>17.6</td>
</tr>
<tr>
<td>11</td>
<td>No U turn</td>
<td>11</td>
<td>85.9</td>
<td>7.8</td>
</tr>
<tr>
<td>12</td>
<td>Priority to on coming traffic</td>
<td>2</td>
<td>47.6</td>
<td>23.8</td>
</tr>
<tr>
<td>13</td>
<td>Closed to motor cars</td>
<td>1.0</td>
<td>62.5</td>
<td>62.5</td>
</tr>
<tr>
<td>14</td>
<td>End of prohibition of goods vehicles</td>
<td>5</td>
<td>32.6</td>
<td>6.5</td>
</tr>
<tr>
<td>15</td>
<td>No entry for vehicular traffic</td>
<td>105</td>
<td>72.0</td>
<td>0.7</td>
</tr>
<tr>
<td>16</td>
<td>Turn left ahead</td>
<td>141</td>
<td>77.9</td>
<td>0.6</td>
</tr>
<tr>
<td>17</td>
<td>Vehicles may pass either side</td>
<td>10</td>
<td>16.3</td>
<td>1.6</td>
</tr>
<tr>
<td>18</td>
<td>Keep right</td>
<td>141</td>
<td>62.1</td>
<td>0.4</td>
</tr>
<tr>
<td>19</td>
<td>Staggered junction</td>
<td>1.5</td>
<td>21.4</td>
<td>14.2</td>
</tr>
<tr>
<td>20</td>
<td>Traffic merges from left</td>
<td>120</td>
<td>38.7</td>
<td>0.3</td>
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<tr>
<td>21</td>
<td>Road narrows from both sides</td>
<td>1.5</td>
<td>76.5</td>
<td>51.0</td>
</tr>
<tr>
<td>22</td>
<td>Dual carriage with 3 lanes- right hand lane is closed</td>
<td>13</td>
<td>86.0</td>
<td>6.6</td>
</tr>
<tr>
<td>23</td>
<td>Slippery road</td>
<td>1.0</td>
<td>84.2</td>
<td>84.2</td>
</tr>
</tbody>
</table>
Table 2 Signs equally understood by Arab, Asian, and Westerner drivers (at 0.05 level)

<table>
<thead>
<tr>
<th>Sign no. as appeared in the questionnaire</th>
<th>Title of the sign</th>
<th>Percentage of drivers’ correct identification of signs per 1000 km</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Arabs (n=1543)</td>
<td>Arabs (n=303)</td>
<td>Europeans &amp; American (n=150)</td>
<td>Others (n=33)</td>
<td>F-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>No pedestrians are allowed to pass</td>
<td>3.27</td>
<td>3.47</td>
<td>4.37</td>
<td>4.41</td>
<td>1.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Turn left</td>
<td>0.54</td>
<td>0.44</td>
<td>0.52</td>
<td>0.52</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Maximum speed limit</td>
<td>0.11</td>
<td>0.12</td>
<td>0.11</td>
<td>0.10</td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>No stopping</td>
<td>0.69</td>
<td>0.60</td>
<td>0.68</td>
<td>0.59</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>No right turn</td>
<td>1.80</td>
<td>1.84</td>
<td>1.84</td>
<td>1.77</td>
<td>3.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>No waiting</td>
<td>3.64</td>
<td>4.07</td>
<td>4.13</td>
<td>4.33</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>No entry for vehicular traffic</td>
<td>0.66</td>
<td>0.82</td>
<td>0.77</td>
<td>0.74</td>
<td>11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Dual carriage with 3 lanes- right hand lane is closed</td>
<td>6.53</td>
<td>6.95</td>
<td>7.04</td>
<td>6.47</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Road narrows on left ahead</td>
<td>3.91</td>
<td>4.39</td>
<td>4.52</td>
<td>4.29</td>
<td>0.1</td>
<td></td>
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</table>
Table 3 Signs poorly understood by Arab and Asian drivers, at 0.05 level, compared with Westerners

<table>
<thead>
<tr>
<th>Sign no. as appeared in the questionnaire</th>
<th>Title of the sign</th>
<th>Percentage of drivers’ correct identification of signs per 1000 km</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>End of prohibition of overtaking</td>
<td>16.57</td>
<td>19.60</td>
</tr>
<tr>
<td>12</td>
<td>Priority to oncoming traffic</td>
<td>21.81</td>
<td>29.13</td>
</tr>
<tr>
<td>13</td>
<td>Closed to motor cars</td>
<td>60.90</td>
<td>66.30</td>
</tr>
<tr>
<td>14</td>
<td>End of prohibition of goods vehicles</td>
<td>5.94</td>
<td>7.75</td>
</tr>
<tr>
<td>18</td>
<td>Keep right</td>
<td>0.42</td>
<td>0.50</td>
</tr>
<tr>
<td>19</td>
<td>Staggered junction</td>
<td>11.31</td>
<td>18.65</td>
</tr>
<tr>
<td>26</td>
<td>Diversion to opposite</td>
<td>26.88</td>
<td>24.20</td>
</tr>
<tr>
<td>29</td>
<td>Other danger plate indicates nature of danger</td>
<td>0.38</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Table 4 Signs poorly understood by Arab drivers, at 0.05 level, compared with Westerners

<table>
<thead>
<tr>
<th>Sign no. as appeared in the questionnaire</th>
<th>Title of the sign</th>
<th>Percentage of drivers’ correct identification of signs per 1000 km</th>
<th>F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Arabs (n=1543)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asians (n=303)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Europeans &amp; Americans (n=150)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others (n=33)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Axle weight limit</td>
<td>22.4</td>
<td>24.1</td>
</tr>
<tr>
<td>2</td>
<td>Mini roundabout</td>
<td>0.68</td>
<td>1.28</td>
</tr>
<tr>
<td>5</td>
<td>Maximum height limit</td>
<td>0.77</td>
<td>0.90</td>
</tr>
<tr>
<td>11</td>
<td>No U turn</td>
<td>7.61</td>
<td>8.08</td>
</tr>
<tr>
<td>16</td>
<td>Turn left ahead</td>
<td>0.53</td>
<td>0.59</td>
</tr>
<tr>
<td>17</td>
<td>Vehicles may pass either side</td>
<td>1.13</td>
<td>3.17</td>
</tr>
<tr>
<td>20</td>
<td>Traffic merges from left</td>
<td>0.30</td>
<td>0.48</td>
</tr>
<tr>
<td>21</td>
<td>Road narrows from both sides</td>
<td>48.6</td>
<td>53.97</td>
</tr>
<tr>
<td>23</td>
<td>Slippery road</td>
<td>82.4</td>
<td>79.37</td>
</tr>
<tr>
<td>25</td>
<td>Dual carriage way ends</td>
<td>42.4</td>
<td>55.03</td>
</tr>
<tr>
<td>28</td>
<td>Hump bridge ahead</td>
<td>31.30</td>
<td>60.32</td>
</tr>
</tbody>
</table>

F-test values indicate statistical significance at the 0.05 level.
Session 6. VULNERABLE AND OLD ROAD USERS

Age-related functional impairments and the impact on the ability to cross roads safely
Jennie Oxley, Monash University, Australia

Development of a national licence assessment program for older drivers in Australasia
Jim Langford, Monash University, Australia

Bus and coach passenger casualties in non-collision incidents
Allan Kirk, The Research Institute for Consumer Ergonomics, UK

Investigation of accident involving vulnerable road users in Greek urban areas
Socrates Basbas, Aristotle University of Thessalonki, Greece

Modeling pedestrians’ crossing behaviour: Some empirical evidence
Mohammad M. Hamed, Jordan
AGE-RELATED FUNCTIONAL IMPAIRMENTS AND THE IMPACT ON THE ABILITY TO CROSS ROADS SAFELY.

Jennifer Oxley*, Elfriede Ihsen+, Brian Fildes*, and Judith Charlton*

* Accident Research Centre, Monash University, Victoria Australia.
+ Department of Psychology, Swinburne University of Technology, Victoria, Australia

Abstract

Safe pedestrian travel is an important factor in maintaining mobility for older road users. However, the task of making gap judgements in order to cross roads safely may place high demands on older pedestrians and it is possible that they are at increased risk as a result of age-related sensory, cognitive and physical limitations. This paper describes an experiment conducted to investigate the effect of age and age-related changes in functional performance on crossing decisions in a simulated road environment. The findings suggest that age and age-related declines in physical, perceptual and cognitive function are associated with an increased likelihood of making an incorrect (unsafe) crossing decisions. These findings have practical implications for behavioural and engineering road safety countermeasures for reducing older pedestrian crashes.

INTRODUCTION

Pedestrian travel is a major travel mode, even in highly motorised countries, and all road users are pedestrians for at least some of the time they are using the road system. While its importance has been under-estimated in the past, walking is vital to the mobility of older road users, not only to carry out essential daily tasks, but it is also an important factor in maintaining social contacts and exercise. It follows, then, that safe pedestrian travel is an important factor in maintaining mobility for older road users. Pedestrians, however, are a vulnerable road user group and older pedestrians, in particular, are at great risk of injury or death when involved in a crash.

Crash statistics world-wide show that the elderly are involved in significantly more serious injury and fatal pedestrian crashes than younger adults per head of population and number of roads crossed (Carthey, Packham, Salter & Silcock, 1995; Fontaine & Gourlet, 1997; Australian Transport Safety Bureau, 2000). Many factors are likely to contribute to the greater crash risk for older pedestrians including increased frailty and susceptibility to injury, driver behaviour and attitudes, and the behaviour of older pedestrians.

In order to cross a road safely without engineering assistance, pedestrians must, while approaching or stopping at the edge of the road, inspect the roadway in both directions and look for approaching vehicles. This part of the task involves detecting objects in motion, ascertaining the direction and velocity of objects, the identity of the object and estimating when the vehicle will arrive at the crossing point. Furthermore, pedestrians must, on many roads, integrate and remember information about traffic in both directions and in multiple lanes as well as combine vehicle arrival times with own walking speed in order to reach a decision to cross. Once a decision has been reached pedestrians must initiate and carry out actions as quickly as possible to achieve a safe road-crossing.
Making a decision to cross the road, therefore, is a complex task requiring intact perceptual, cognitive and physical skills. Accurate perception of the motion of the approaching vehicle is paramount when making judgements of the traffic in which to cross safely. However, the task of making gap judgements by estimating the time-of-arrival of the closest vehicle in order to cross the road safely may place high demands on older adults, especially in conditions of uncertainty or when a decision needs to be made quickly.

There is some evidence of age-related deficits in motion detection. Observational studies showed that, compared to younger pedestrians, older pedestrians experience difficulties selecting safe gaps in which to cross in complex two-way traffic. The oldest and slowest pedestrians often leave very short margins between reaching safety and the oncoming vehicles passing the crossing point (Oxley, Fildes, Ihsen, Charlton & Day, 1997a). Experimental studies also show that older adults experience difficulty perceiving the details of moving objects (Burg, 1966; Kosnik, Winslow, Kline, Rasinski & Sekuler, 1988), tracking fast moving stimuli (Sharp & Sylvester, 1978) and are less accurate than younger adults estimating time-of-arrival (Schiff, Oldak & Shah, 1992). The processes involved in making these estimates, however, are not clear.

While the role of age-related functional impairment in driving performance and crash risk has been well researched and many links have been established, these links are not well established for pedestrian performance. For example, clear associations between driving performance and performance on functional assessment tests of dynamic visual acuity, useful field of view, visual search, divided attention and mental status have been found (Cooper, Tallman, Tuokko & Beattie, 1993; Janke, 1994; Ball, Owsley, Sloane, Roeneker & Bruni, 1993). However, little is known about what visual, perceptual and cognitive functions are important for safe road-crossing and few studies have investigated the extent to which the road-crossing behaviour and functional performance of older pedestrians increases their risk of crash involvement.

The experiment described in this paper examines age differences in road-crossing decisions in a simulated crossing environment and reports on the association of functional performance with ability to make appropriate crossing decisions.

**METHOD**

Experimental studies simulating real-world skills have long been recognised as an important method for examining human performance. This approach was used here to study the crossing responses of individuals and their perceptions of safety in traffic situations that might have serious negative consequences in real life. Following a validation of the simulated road-crossing task against real-world road crossing behaviour (Oxley, Fildes, Ihsen, Charlton & Day, 1997b), this experiment examined in detail the factors involved in estimating gaps in the traffic and examined age differences in this ability between younger and older adults. Tests of functional performance were also completed by participants and test scores were compared with the likelihood of making an appropriate crossing decision to examine the role of functional performance in crash risk.

**Participants**

Fifty-four participants took part in this study. Three groups consisted of 18 young adults aged between 30 and 45 years, 18 ‘young-old’ adults aged between 60 and 69 years, and 18 ‘old-old’ adults aged 75 years and over. All participants were volunteers and in good health.
The simulated road environment

A simulated road environment depicting an undivided two-way residential road from the perspective of a pedestrian waiting at the kerb was utilised in this experiment. Moving traffic scenes of two near-side approaching vehicles (that is, vehicles travelling from the right from the perspective of the pedestrian in Australia¹) were presented to participants. The depicted road was straight with features such as houses, fences, trees and other roadway markings selected to make the environment look as realistic as possible. In addition, relatively realistic sounds of approaching and passing cars were included in all scenes. No far-side traffic appeared in the scenes. An illustration of this image is provided in Figure 1.

![Figure 1: Stimulus traffic scenarios presented in the road-crossing simulation. (Note: the road appeared straight when projected onto a curved presentation screen).](image)

Traffic scenes were generated from data files from a mid-level driving simulator, downloaded onto three VCR tapes (each containing 15 scenes in random order) and projected onto a large curved white screen. Time gap and speed of vehicles were manipulated with five levels of time gap (1, 4, 7, 10 & 13s) and three levels of vehicle speed (40, 60 & 80 km/h). The levels of time gap were chosen on the basis of group average walking speeds identified in previous observational studies (Oxley et al., 1997), and represented theoretically safe and unsafe time gaps. Each participant viewed traffic scenes on all three video tapes in which the presentation was counterbalanced. Thus, each participant viewed the fifteen scenes three times, that is, a total of 45 scenes.

Tests of functional performance

All participants completed a battery of functional assessments designed to assess visual, attentional, cognitive and physical abilities. These included the Verbaken high/low contrast visual acuity test, the Trail-making tests (Parts A and B), the Digit-Symbol test (a sub-test of the WAIS), the Mattis Organic Mental Syndrome Screening Examination (MOMSSE) (a shortened version of the Dementia Rating Scale), measures of walking time (fast and normal walking pace) and the ‘get-up-and-go’ test (assessment of physical agility).

¹ Vehicles in Australia drive on the left-hand side of the road, and contrary to those in USA and most European countries.
**Procedure**

Tests of functional performance were administered initially and all participants completed each test. Following this, participants undertook the road-crossing task. Participants were seated at a desk in a darkened quiet room in front of the screen on which the image was projected. They were instructed to respond to each traffic scene as if they were to cross the road immediately behind the first passing ‘trigger’ vehicle and in front of the second ‘approaching’ vehicle. A buzzer sounded as the first vehicle passed (and activated a timer), and participants were instructed to look at the traffic at this time and make a simple ‘yes’ or ‘no’ response on a keyboard to indicate whether they would have ‘crossed’ or not. Yes/no responses and decision time were recorded. Participants were given practice trials until they fully understood the task.

**RESULTS**

**Yes/no responses**

These responses indicated whether individuals would have ‘crossed’ the road or not in front of the second approaching vehicle. Given that group differences were found in walking time, analysis of crossing responses was undertaken by employing hierarchical logistic regression modelling of the data to examine the independent variables including age group, time gap, vehicle speed and distance gap while holding the effects of walking time statistically constant. Mean normal walking times were 3.9s, 4.6s and 7s for young, young-old and old-old participants respectively. Tukey tests revealed that walking times of young and young-old participants did not differ, however, the old-old group walked slower than both younger groups, p’s < 0.001.

All variables were significant predictors of crossing decisions: walking time, $\chi^2(1) = 32.33$, p < 0.001, $R^2 = 0.10$, time gap, $\chi^2(4) = 191.33$, p < 0.001, $R^2 = 0.24$, vehicle speed, $\chi^2(2) = 90.76$, p < 0.001, $R^2 = 0.16$, and distance gap, $\chi^2(14) = 426.27$, p < 0.001, $R^2 = 0.36$. An interaction between time gap and age group was also found, $\chi^2(8) = 152.53$, p < 0.001, $R^2 = 0.21$.

Figure 2 shows the proportion of ‘yes’ crossing responses by distance gap, vehicle speed and time gap for each age group. It should be noted that distance gap does not increase in a linear way with time gap because of speed manipulations. It is for this reason that corresponding time gap and vehicle speed measures are also provided on the x-axis.

These data show that participants were less likely to indicate that they would cross when time and distance gaps were small than when they were larger. The young-old and old-old groups were less likely to cross than the younger group when distance gaps were smaller than about 110 m. At distances of 22m and below (time gap of 1s) the response rate was close to zero for all three groups. Beyond that, the proportion of ‘yes’ responses increased rapidly for the young participants who reached asymptote when the vehicle was more than 100m or 7s away from them. Response rates for the other two groups increased more gradually and they reached asymptote later (young-old group at about 150m or 10s and the old-old group at about 200m or 13s).

Of particular interest in these data is the difference in the proportion of ‘yes’ crossing responses where time gap remained constant but distance gap varied. For instance, for the three time gap conditions of 4s, the proportion of ‘yes’ crossing responses increased as distance gap increased from 44.4m to 66.7m to 88.9m for all participants. A similar trend was also apparent for longer time gap conditions, particularly for the two older groups. This suggests that the distance away of the vehicle, and not time gap or vehicle speed, was the main determinant of crossing decisions for all groups. However, these data also show that...
time gap did contribute to crossing decisions. Inspection of the proportion of ‘yes’ responses in the 88.9m/4s and 77.7m/7s conditions show that participants were more likely to respond ‘yes’ in the 7s time gap condition even though the corresponding distance gap was smaller than that in the 4s time condition.

Figure 2: Proportion of ‘yes’ crossing responses – age group by distance gap, time gap and vehicle speed.

An additional analysis was carried out to compare actual proportions of ‘yes’ responses of young-old and old-old participants with those predicted on the basis of their average walking speed relative to the average walking speed of the young group (1.54m/s). Average walking speed of the young-old participants (1.22m/s) expressed as a proportion of the walking speed of young participants is 84%. Likewise, average walking speed of old-old participants expressed as a proportion of the walking speed of young participants is 55%. This means that, if 100% of young participants responded ‘yes’ then the predicted proportion of young-old and old-old participants responding ‘yes’ in that same condition would be 84% and 55% respectively. Predicted values of positive responses for young-old and old-old participants are shown for critical gaps (unsafe based on average walking times of older participants) between 4s and 10s in Figure 2.

The actual response rate of the young-old participants was more conservative than the expected one up to distance gaps of about 90m and time gaps of 4s. For distance and time gaps above these levels, their response rate was at predicted levels or just above. In contrast, while old-old participants also made conservative decisions when distance and time gaps were short, their response rates greatly exceeded the expected level at the longer distance and time gaps. This indicates that old-old participants tended to make unsafe crossing decisions when vehicles were at least 100m or 7s away from them.

Correct/incorrect responses
While a ‘yes’ or ‘no’ response in itself is an interesting measure, the response needs to be put into the context of whether it was ‘correct’ (safe) or ‘incorrect’ (unsafe or missed opportunity), allowing for
walking time and decision time, particularly in critical time gaps (4s and 7s). As noted previously, group differences were found for walking time, and for decision time. Mean decision times were 0.66s, 0.88s and 1.44s for the young, young-old and old-old groups, respectively. Overall, the young group responded quicker in all traffic conditions than the young-old group, who in turn responded quicker than the old-old group, p’s < 0.001. Correct and incorrect responses were scored in the following way. If an individual with a combined walking and decision time of 5s responded ‘yes’ in the 4s time gap condition, that response would be recorded as an ‘incorrect’ (or unsafe) response. If a ‘no’ response was made in this time gap condition, it would be a ‘correct’ (or safe) response. If a ‘yes’ response was made by this person with the same combined walking and decision time in the 7s time gap condition, that response would have been recorded as a ‘correct’ response. Conversely, if a ‘no’ response was made in this time gap condition, it would be an ‘incorrect’ (or missed opportunity) response. Figure 3 shows the proportion of correct ‘yes’ and ‘no’ responses for the critical time gaps of 4s and 7s and demonstrates clear group and time gap condition differences.

![YES RESPONSES](image)

![NO RESPONSES](image)

Figure 3: Proportion of ‘correct’ responses by age group for both ‘yes’ and ‘no’ crossing responses.

A logistic regression model was employed to predict correct response as a function of age group, time gap, yes/no responses and their interactions. The model fitted the data well, with an $R^2$ value of 0.71. The analysis revealed that age group and time gap were predictors of correct responses. Interactions were found between age group and time gap, $\chi^2(2) = 5.946, p = 0.05$, between age group and yes/no response,
\( \chi^2(2) = 99.203, p < 0.05, \) and between time gap and yes/no response, \( \chi^2(1) = 95.243, p < 0.001. \) Overall, the young group was more likely to make a correct ‘yes’ response than the older groups in both the 4s and 7s time gap conditions. Young participants who responded ‘yes’ in the 7s time gap were correct 100% of the time, and, in the 4s time gap, the proportion of correct ‘yes’ responses dropped to 54%. Young-old participants who responded ‘yes’ in the 7s time gap, were correct 99% of the time, however, this dropped markedly to only 3% in the 4s time gap condition. In contrast, old-old participants were less likely to be correct than their younger counterparts when they responded ‘yes’ in both the 4s and 7s time gap conditions. They were correct only 38% of the time in the 7s time gap condition and incorrect all of the time in the 4s time gap condition. It is interesting to note that the young-old group performed similarly to the young group in the 7s time gap condition and made a correct ‘yes’ response most of the time, however, performed more like the old-old group in the 4s time gap condition, rarely making a correct ‘yes’ response. This finding shows that young-old participants experienced more problems when the time gap was shorter or more critical than when the time gap was longer.

Not surprisingly, the ‘no’ responses showed an inverse relationship to the ‘yes’ responses. While the old-old group was more likely than their younger counterparts to respond ‘no’, particularly in the 4s time gap, they were also more likely to make a correct ‘no’ response. Only a few young and young-old participants made a ‘no’ response in the 7s time gap condition, and of those who did, most made an incorrect response. Like for the ‘yes’ responses, the young-old group performed similarly to the young group in the 7s time gap condition when making a ‘no’ response, however, performed more like the old-old group in the 4s time gap condition.

The role of functional performance on ability to cross roads safely

The initial analyses considered age group membership as a predictor of crossing decisions and the findings suggest that age itself is a good predictor of ability to cross roads safely. The main focus, however, of this research was to examine the effect of functional performance on the ability to cross roads safely. Table 1 presents mean scores on each functional assessment test by age group. Tests of physical function were scored in seconds, thus a higher score equates to poorer physical performance. For tests of visual acuity, the score was based on the size of the letters read and number of errors on the last line. A score of 1.0 is normal and 0.1 is legally blind, therefore a lower score equates to poorer visual acuity. Scores on the Trail-making tests are the time (in seconds) to complete each part, thus a higher score equates to poorer physical performance. For the Digit/symbol test, the score is measured from the number of correct responses given in a set time period, therefore, a lower score equates to poorer performance. For the MOMSEE, points are scored for correct responses in each sub-test. The total score is the sum of scores on each sub-test and has a maximum of 59 points, thus a lower score equates to poorer cognitive performance.

For all tests, performance declined significantly with age. Simple one-way ANOVAs with post hoc Tukey tests were performed on the data for each assessment, examining differences between age groups. In comparison with the young group, the old-old group performed more poorly on all tests. In comparison with the young-old group, too, the old-old group performed more poorly on physical tests, Trail-making tests (parts A and B), digit/symbol test and the MOMSEE assessment for mental status. No significant difference in visual acuity was found between the young-old and old-old groups, except under one low contrast condition.

In order to examine the association between performance on functional assessments and ability to make appropriate crossing decisions, comparisons between ‘correct/incorrect’ responses in the most critical time gap conditions (4s and 7s) and functional performance were made. Given that the decision to cross the road rather than wait may be a better predictor of ‘riskiness’ based on a safety outcome, and that the fit of the model to the ‘yes’ response was as good as the complete data (\( R^2 = 0.70 \)), ‘yes’ responses only were considered in the following analyses.
Table 1: Mean score on functional assessment tests by age group.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Young Group (n=18)</th>
<th>Mean Score</th>
<th>SD</th>
<th>Young-Old Group (n=18)</th>
<th>Mean Score</th>
<th>SD</th>
<th>Old-Old Group (n=18)</th>
<th>Mean Score</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get-up-and-go</td>
<td></td>
<td>6.15s</td>
<td>0.97s</td>
<td></td>
<td>7.86s</td>
<td>1.05s</td>
<td>11.43s ***</td>
<td>2.94s</td>
<td></td>
</tr>
<tr>
<td>Normal walking time</td>
<td></td>
<td>3.87s</td>
<td>0.31s</td>
<td></td>
<td>4.60s</td>
<td>0.61</td>
<td>6.96s ***</td>
<td>1.57s</td>
<td></td>
</tr>
<tr>
<td>Fast walking time</td>
<td></td>
<td>2.77s</td>
<td>0.32s</td>
<td></td>
<td>3.57s</td>
<td>0.55</td>
<td>5.74s ***</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>Visual acuity (r/low)</td>
<td></td>
<td>0.75</td>
<td>0.22</td>
<td></td>
<td>0.37</td>
<td>0.11</td>
<td>0.32</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Visual acuity (r/high)</td>
<td></td>
<td>1.17</td>
<td>0.24</td>
<td></td>
<td>0.62</td>
<td>0.22</td>
<td>0.63</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Visual acuity (l/low)</td>
<td></td>
<td>0.74</td>
<td>0.24</td>
<td></td>
<td>0.39</td>
<td>0.12</td>
<td>0.31 *</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Visual acuity (l/high)</td>
<td></td>
<td>1.14</td>
<td>0.29</td>
<td></td>
<td>0.68</td>
<td>0.23</td>
<td>0.61</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Trail-making test (A)</td>
<td></td>
<td>21.71s</td>
<td>4.85</td>
<td></td>
<td>38.13s ***</td>
<td>12.68</td>
<td>61.80s ***</td>
<td>23.06</td>
<td></td>
</tr>
<tr>
<td>Trail-making test (B)</td>
<td></td>
<td>51.40s</td>
<td>12.97</td>
<td></td>
<td>90.26s **</td>
<td>36.68</td>
<td>131.77s **</td>
<td>53.87</td>
<td></td>
</tr>
<tr>
<td>Digit/symbol</td>
<td></td>
<td>67.39</td>
<td>6.89</td>
<td></td>
<td>47.83 ***</td>
<td>9.29</td>
<td>35.83 ***</td>
<td>9.78</td>
<td></td>
</tr>
<tr>
<td>MOMSSE</td>
<td></td>
<td>53.39</td>
<td>1.29</td>
<td></td>
<td>49.61 ***</td>
<td>3.35</td>
<td>45.72 ***</td>
<td>5.80</td>
<td></td>
</tr>
</tbody>
</table>

*** p < 0.001
*  p < 0.05

A series of logistic regression analyses were performed on the ‘yes’ response data to examine the association between each functional assessment test and ability to make a correct ‘yes’ responses in both time gap conditions. Each regression model included the functional assessment measure along with the time gap condition as predictors. Interactions between time gap and score on functional assessments were considered, however, they did not improve the model significantly and were therefore not included in the final analyses. In addition, walking time was not included in these analyses as this measure was used to generate the ‘correct/incorrect’ response variable. A summary of the outcomes of these analyses is provided in Table 2.
Table 2: Summary of logistic regression analysis outcomes for each functional assessment test

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Wald Statistic</th>
<th>R² Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Get-up-and-go</td>
<td>97.55 *</td>
<td>0.720</td>
</tr>
<tr>
<td>Mean Visual Acuity</td>
<td>43.64 *</td>
<td>0.375</td>
</tr>
<tr>
<td>Trail-Making Tests (Part A)</td>
<td>74.05 *</td>
<td>0.469</td>
</tr>
<tr>
<td>Trail-Making Test (Part B)</td>
<td>71.01 *</td>
<td>0.451</td>
</tr>
<tr>
<td>Digit/Symbol Test</td>
<td>99.73 *</td>
<td>0.604</td>
</tr>
<tr>
<td>MOMSSE</td>
<td>77.57 *</td>
<td>0.461</td>
</tr>
</tbody>
</table>
* p < 0.001

All tests of functional performance were predictors of correct ‘yes’ responses, shown by the high and significant $\chi^2$ values in Table 2. This means that the better one performs on any of the functional assessment measures, the more likely a correct ‘yes’ response would be made. Conversely, poor performance on these tests is associated with the probability of making an incorrect ‘yes’ response. The get-up-and-go test was the strongest predictor of correct response suggesting that individuals with good physical ability were more likely to make a correct ‘yes’ response than those who were slow to complete the test, demonstrated by $R^2$ values. The digit/symbol test also predicted responses strongly, suggesting that individuals with good visuo-motor co-ordination, fine motor speed, divided attentional skills and speed of cognitive operations were more likely than individuals whose abilities were poorer to make a correct ‘yes’ response. While still significant, visual acuity was the least strongest predictor of a correct ‘yes’ response among these participants.

DISCUSSION

The experiment reported here has provided a detailed account of decision-making processes on crossing the road, highlighting differences between crossing responses younger and older adults regarding gaps in the traffic in which to cross roads safely. In addition, it has demonstrated a significant association between performance on physical, perceptual and cognitive skills and road crossing responses that may, in part, contribute to the increased crash and injury rates of older pedestrians.

Predictors of yes/no responses

Overall, the findings of this experiment demonstrated that, in general, the likelihood of a ‘yes’ crossing response increased as time and distance gaps increased for all participant groups. However, those aged 60-69 years (the young-old participants) and those aged 75 years and older (the old-old participants) were less likely than their younger counterparts to indicate that they would have crossed with distances less than 110m and time gaps less than 10s. It was appropriate for the old-old participants to indicate that they needed larger gaps than younger participants, as their walking times were significantly longer and indicates that, at least to some extent, they adjusted to their slower walking times when deciding whether it was safe to cross. However, despite leaving larger gaps, many of the old-old participants decided to cross when in reality their walking times predicted that this was not safe, particularly when the vehicle was further away. It is possible that the old-old participants had difficulty compensating physically or cognitively fully for their slower walking speed. The data also indicate that the young-old participants seemed to be more cautious than they needed to be at shorter distance and time gaps. At these gaps their actual response rates were lower than those predicted on the basis of their walking speed. At longer
distance and time gaps, their actual response rates matched the estimated ones reasonably well. This may indicate that this age group were acutely aware of their failing abilities whereas the old-old participants have lost such insight.

Of particular interest, the results showed that it was not only the old-old adults who based their decision on distance gaps rather than time gaps, but distance seemed to be the primary determinant of crossing decisions for all age groups. In other words, all participants appeared to rely more on spatial than temporal information about oncoming vehicles to make a crossing decision, and particularly the very old ones. It was clear, however, that temporal information, or the speed of the vehicle, also contributed to some degree to the crossing decisions for all age groups. In some conditions it was found that response rates increased or did not change with an increase in time gap and a corresponding decrease in distance gap. If the distance of the vehicle had been the only deciding factor, responses should have decreased under these conditions. While this appears to be a relatively safe strategy for young and young-old people, it is a risky one for the oldest members of our community. Due to their slower walking speeds and other sensory and cognitive limitations, older pedestrians may be at significant risk of collision with oncoming vehicles unless their time-of-arrival is fully considered.

Correctness of responses
The ability to make correct responses, allowing for walking time and decision time, is intuitively a major determinant of safe pedestrian performance, particularly in critical time gaps. However, the analysis revealed clear age differences in proportions of correct ‘yes’ and ‘no’ responses. Of the young participants that responded ‘yes’, the majority made a correct (safe) decision, even in the short time gap of 4s. In contrast, for those old-old participants that responded ‘yes’ in critical time gaps, they were correct less than 40 percent of the time, suggesting that a substantial number of old-old pedestrians made risky crossing decisions. The most alarming result was that, for those old-old participants who responded ‘yes’ in the 4s time gap, none made a correct response. In the real world, these crossing decisions have the potential to result in a collision. Interestingly, the young-old group behaved similarly to the young group when the time gap was longer, making a high proportion of correct (safe) responses. However, their proportion of correct responses was more like that of the old-old group in the short time gap condition, with few of them making a correct (safe) response. This finding would imply that they experienced more difficulty responding correctly (and safely) when time gaps were small, suggesting that even at these ages (60-69 years) information processing ability is changing.

With regard to correctness of ‘no’ responses, the old-old group were more likely to make a correct ‘no’ response than the two younger groups, particularly when time gaps were shorter, suggesting that they were aware of slower walking speeds and compensated appropriately for declining physical abilities. An incorrect ‘no’ response corresponds to a missed opportunity and suggests that responses were conservative. While this type of response might be a preferred strategy for older pedestrians, given their physical and cognitive limitations, a missed opportunity might have some negative consequences such as greater pressure to cross after a long wait. Those in the old-old group that responded ‘no’ in the longer time gap condition were more likely to be incorrect than for the shorter time gap, suggesting a substantial amount of conservativeness. The data also suggests some conservativeness for young and young-old participants. Of the young participants that made a ‘no’ response, the majority made an incorrect response, meaning that they said ‘no’ when they could have said ‘yes’ and still crossed safely (a missed opportunity). Like for the ‘yes’ responses, the responses of the young-old group were similar to those of the young group when the time gap was long, but more like that of the old-old group when the time gap was short. This again, suggests some age-related change in information processing ability for this group when under time pressure.
The role of functional performance

In recent years, the appropriateness of using chronological age to determine safety on the road has been questioned. For instance, it has been argued that statistics depicting crash risk by chronological age may lead to the inaccurate conclusion that age per se is the major determinant of driving safety. Waller (1991) further argued that years since birth can be a misnomer in terms of performance ability, may not serve as a predictor of the capabilities of any individual, and may ignore alternative or complementary functional definitions. It is argued that age itself does not lead to crashes – this is evident because crashes are not equally distributed among all ageing drivers and pedestrians. Rather, it seems that age-related declines in particular abilities may be important to safe driving and walking in traffic. Despite these assertions, the current findings suggest that advancing age does increase risk on the road. However, it should be noted that the age groups considered in this experiment were quite distinct from each other and spanned 10-year minimum age cohorts. Moreover, it is a difficult task to separate the effects of age per se and age-related changes in functional performance on crash risk. Given that functional performance varies considerably within age groups, particularly for the older age groups, variability within groups was not able to be clearly identified in the initial analysis. Subsequent analyses, however, demonstrated that physical, perceptual and cognitive skills play some role in safe road-crossing decisions.

Intuitively, good motor performance is of prime importance when crossing roads, particularly the ability to adjust walking pace and execute actions quickly when faced with traffic emergencies. Reduced physical capabilities means that older pedestrians are less mobile and less able to move out of the way of approaching cars. While a number of studies have found that older adults initiate movements and walk more slowly than younger adults (Stelmach & Nahom, 1992; Knoblauch, Pietrucha & Nitzburg, 1996; Eubanks & Hill, 1998; Oxley, 2000), no previous research has associated physical agility with crash risk. The current finding that slower walkers made more incorrect crossing decisions supports Lee, Young and McLaughlin’s (1984) argument that older people may not compensate appropriately for their slower walking speeds. Lee et al claimed that perceiving the affordance of a gap in the traffic entails combining information about the environment with information about one’s walking speed. It is unlikely that slower walking older participants in this study would have intentionally chosen a risky decision strategy in this situation over their younger counterparts. Instead, this finding may be explained as a difficulty in adjusting behaviour to suit changing abilities. As Lee et al argued, while younger adults maintain calibration through daily experience, older adults need to re-calibrate as they become infirm and slower and this may be a very difficult task to achieve.

The findings show that attentional and cognitive abilities also play an important role in the ability to cross roads safely. The finding that participants who performed poorly on tests of visual search, attention and cognitive skill were more likely to make an incorrect ‘yes’ crossing response suggests that the road crossing task places overwhelming demands on attentional and cognitive resources of old-old participants and to a lesser extent for young-old participants. In a complex road environment with approaching traffic, it seems that inabilities in attending to, integrating and processing many sources of information could have reduced the ability to respond safely to the approaching traffic. These include: inflexibility of visual scanning particularly when a rapid decision is required (Rabbitt, 1982); problems in efficiently focussing and switching attention to the most relevant source of information and excluding irrelevant information (Madden, Connelly & Pearce, 1994); and difficulties of working memory, particularly holding information in memory and integrating it with incoming information (Johnston, de Leonardis, Hashtroudi & Ferguson, 1995).

It is interesting to note that the measure of visual acuity, while significant, was not as strong a predictor of correct crossing response as other measures, despite the continued argument that traffic participation is a highly visual task, and with the majority of research on older drivers focussing on the role of age-related visual declines in crash risk (Shinar & Scheiber, 1991; Kosnik, Sekuler & Kline, 1990; Klein, 1991). There is no doubt that vision is important to perform daily activities, to detect potential hazards, and
maintain balance and ambulation, however, static visual acuity may not be the most appropriate measure of visual skill for pedestrian performance. Indeed, previous correlations between static visual acuity and increased risk for drivers of crashing are weak at best (Shinar & Scheiber, 1991; Owens & Andre, 1996). Dynamic visual acuity (the ability to resolve details in a moving target) seems to be a better predictor of crash risk (Burg, 1964, 1967; Hills, 1975; Shinar, 1977) and should be considered in future research. Given that many of the visual requirements for road-crossing require the detection and assessment of changing information on the retina, declines in dynamic visual acuity may lead to inaccurate estimations of vehicular movement.

In summary, this experiment has shown that, although functional assessment tests predicted the ability to cross roads safely, age group was generally a strong predictor of safe crossing decisions. The ‘get-up-and-go’ functional assessment test was the strongest predictor of safe crossing decisions, suggesting that this test encompassed more than age alone. However, all functional assessment measures here did predict safe crossing decisions albeit less strongly. This would suggest that individual functional assessment tests may not discriminate adequately all factors involved in making this decision. It is possible, however, that a combination of these tests can predict safe crossing decisions and is worthy of future research.

CONCLUSIONS

This experiment examined age differences in crossing responses in a simulated road environment. It showed that older participants were less likely to cross a road than younger participants in similar conditions, indicating some awareness of risk and some attempt at compensation for slower walking times. However, the comparison of observed responses of the oldest participants with those predicted based on their walking speeds suggest otherwise. Moreover, the old-old group were also more likely to make an incorrect response when walking and decision times were taken into account. The usefulness of tests of functional performance for predicting crash risk of older pedestrians was also examined here and significant associations between declines in physical, perceptual and cognitive function and the likelihood of making an incorrect crossing response were found. It appears that those with reduced physical, perceptual and cognitive skills (generally the old-old participants) were at increased risk of collision while crossing the road because they were more likely to respond incorrectly to approaching traffic, believing themselves to have more time to cross in safety than in reality. The finding that physical, perceptual and cognitive factors contribute to increased risk of collision reinforces the need for greater emphasis in behavioural and engineering road safety countermeasures for the very old members of our community, especially as these people will be the fastest ageing group in the near future.

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DEVELOPMENT OF A NATIONAL LICENCE ASSESSMENT PROGRAM FOR OLDER DRIVERS IN AUSTRALASIA

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ABSTRACT

Licensing requirements for older drivers in Australasia are varied, with no available evidence that the different assessment procedures have safety benefits. In 1996 the National Highway Traffic Safety Administration in the USA embarked on the development of a national older driver screening and evaluation program for that country. In 1998 Australian and New Zealand transport jurisdictions funded a similar project to develop and trial an appropriate procedure for use in Australasia, to be conducted by the Monash University Accident Research Centre.

A model re-licensing procedure was detailed in 2000, following input from key experts and stakeholders in Australia and New Zealand. Components of the model include:

\begin{itemize}
  \item assessment to target only functionally impaired older drivers;
  \item development of a network of community referral centres;
  \item use of multi-tiered assessment procedures and instruments;
  \item use of a case officer to assist older people through the assessment process;
  \item use of re-training and rehabilitation procedures wherever appropriate;
  \item the licensing authority’s role to include counselling on alternative mobility options, if appropriate.
\end{itemize}

During 2001, further research and development activities include:

\begin{itemize}
  \item a pilot study of the main processes underpinning the model was conducted in Tasmania, to test the acceptability of the model to older drivers, referral agencies and to licensing officers;
  \item a validation study of possible screening instruments to be used in assessment of fitness to drive, is presently being conducted in New Zealand.
\end{itemize}

This paper reports on findings from the pilot and validation studies, as well as giving an overview of the licensing model.

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INTRODUCTION

In terms of absolute accident numbers and when compared with other age groups, older drivers do not represent a major road safety problem in most western societies. However they are involved in significantly more serious injury crashes per distance travelled and the so-called ‘bath tub curve’ shown in Figure 1 (Fildes et al 2001) has been repeatedly confirmed both in Australia and in other Western countries.
Over the next 30 to 50 years, demographic changes are likely to further emphasise the ‘older driver problem’. For example, in OECD member countries, the proportion of the population aged 65 years or more will have doubled by 2050 (OECD Expert Group ERS4, in press). This feature will be particularly marked for the ‘old-old’ where crash risk seems to be at it’s highest: by 2030, there will be a doubling of people aged 80 and over and by 2050, the proportion will have tripled.

The growth in the proportion of older drivers on the road is expected to be considerably greater than demographic changes alone suggest. Increased licensing rates and increased distances driven by the older groups will also contribute to a burgeoning road safety issue (OECD Expert Group ERS4, in press).

Figure 1: Number of serious injury crashes per billion kilometres travelled, Australia, 1996.

![Graph showing the number of serious injury crashes per billion kilometres travelled by age group.]

EXPLAINING OLDER DRIVER CRASHES

Some of the over-involvement of older drivers in serious injury crashes is due to their increased frailty and consequent vulnerability to injury, rather than to reduced driving skills. Research in the USA suggests that males are 2.3 per cent more likely to die in the same severity crash for each year of age above 20, whilst for females this likelihood rises by 2.0 per cent (Evans 1991). Around one-half of the additional fatality risk of drivers aged 75 years or more might be directly attributable to this factor (Maycock 1997, Wylie 1996).

A further explanatory factor is emerging from current research. The early research focused mainly on the deficiencies considered typical of older people, such as the general reduction in physical, sensory and cognitive functioning and consequent association with crash risk. The emphasis is now upon identifying specific sub-groups of older people such as those suffering from dementia, epilepsy or insulin-treated diabetes (Hakamies-Blomqvist, in press). This shift has been from a general approach, “why do older drivers have higher accident risk?”, to a differential focus on high-risk sub-groups, “which older drivers have higher accident risk?” (Hu et al 1998).

The conditions and functional disabilities to which older people seem particularly prone and which have been associated with an increased crash risk (Fildes 1997, Staplin et al 1998 and Austroads 1998), include:
• visual conditions (eg cataracts, glaucoma, diabetic retinopathy, field of view losses);
• cardiac conditions (eg irregular heartbeat, history of heart problems, severe angina);
• cerebrovascular conditions (eg stroke with permanent impairment, history of transient ischaemic attacks);
• insulin-dependent hypoglycaemia;
• reduced memory and cognitive skills (eg moderate and severe dementia including Alzheimer’s and Parkinsons diseases);
• mental illness (eg severe depression, inability to maintain a normal social, mental or emotional state of mind);
• severe muscular and skeletal disorder (including severe arthritis);
• a range of conditions resulting in loss of upper or lower body strength;
• a history of falling;
• conditions resulting in widespread use of particular prescribed drugs and polypharmacy (eg anti-depressants and anti-anxiety drugs);
• alcoholism and drug abuse;
• sleep disorders (sleep apnoea, narcolepsy);
• neurological conditions (eg multiple sclerosis and Parkinsons disease).

RE-LICENSING REQUIREMENTS FOR OLDER DRIVERS

The perception that older drivers commonly suffer from diminished driving skills, has led many jurisdictions to institute mandatory age-based re-assessment. Examples of different licensing practices are given in Table 1.

Table 1 - Licensing procedures in some OECD countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Renewal Procedures?</th>
<th>Renewal Interval</th>
<th>Medical Requirements for Renewal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Yes, mainly</td>
<td>Usually around age 75</td>
<td>Yes, mainly</td>
</tr>
<tr>
<td>Belgium</td>
<td>No</td>
<td>No renewal required</td>
<td>No</td>
</tr>
<tr>
<td>Denmark</td>
<td>Yes</td>
<td>At age 70, licenses issued for 4 years</td>
<td>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At age 71, issued for 3 years</td>
<td>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At ages 72-79, issued for 2 years</td>
<td>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At ages 80+, issued for 1 year</td>
<td>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>If illness, shorter terms possible</td>
<td>)</td>
</tr>
<tr>
<td>England</td>
<td>Yes</td>
<td>At age 70, mandatory renewal</td>
<td>After age 70, a medical certificate and vision test</td>
</tr>
<tr>
<td>Finland</td>
<td>Yes</td>
<td>At age 45, renewal every 5 years</td>
<td>Yes, after age 45 medical review every five years. Renewal requires medical exam and verification of ability by two people</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Renewal period depends on the physician</td>
<td>)</td>
</tr>
<tr>
<td>France</td>
<td>No</td>
<td>No renewal required</td>
<td>No</td>
</tr>
<tr>
<td>Germany</td>
<td>No</td>
<td>Renewal not determined by age</td>
<td>No</td>
</tr>
<tr>
<td>Ireland</td>
<td>Yes</td>
<td>Annual renewal regardless of age</td>
<td>Yes, a certificate of medical fitness</td>
</tr>
<tr>
<td>Italy</td>
<td>Yes</td>
<td>10 year renewal up to age 50, 5 year renewal after age 50 and 3 year renewal at age 70</td>
<td>Medical test required with renewal</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Yes</td>
<td>At age 70, medical review required every five years</td>
<td>Depending on physical conditions, medical review may be more frequent, vision test required</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Yes</td>
<td>No renewal required until age 71 At age 71, renewed for 5 years At age 76, renewed every two years</td>
<td>Yes, at age 71 onwards, medical review and eyesight test required</td>
</tr>
<tr>
<td>------------</td>
<td>-----</td>
<td>----------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Portugal</td>
<td>Yes</td>
<td>At age 70, license renewed every 2 years</td>
<td>Yes, a age 70 a medical exam is required every 2 years</td>
</tr>
<tr>
<td>Sweden</td>
<td>No</td>
<td>No renewal required</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: OECD Expert Group ERS4, in press

In addition to requiring medical reports at various ages, many jurisdictions also require older drivers to pass on-road driving tests. As with the structure and scope of the medical reports, the driving tests differ widely in timing, design and in validity.

THE CASE AGAINST MANDATORY TESTING OF OLDER DRIVERS

A theoretical argument against mandatory testing

Assume that the acceptable risk of a road fatality is 1 per 10,000 drivers a year. Further assume that a factor which doubles the risk, making it 1 per 5,000 drivers a year, is targeted. Finally assume that a test with 100 percent sensitivity and specificity for this risk factor exists.

To prevent one fatality per year, 5,000 at-risk drivers would need to cease driving. In other words, 4,999 ex-drivers would be required to use other transport modes, perhaps incurring greater fatality risk than they did as drivers (OECD Expert Group ERS4, in press).

A practical argument against mandatory testing: it cannot be shown to work

One of the few evaluations of existing driver testing programs has compared the Finnish and Swedish licensing practices (Hakamies-Blomqvist et al 1996). Finland requires regular medical checks at age 70 onwards for licence renewal, whereas Sweden has no age-related controls. No safety benefits of the Finnish program could be detected compared to Sweden.

An Australian study conducted during the 1980s reached a similar conclusion (Torpey 1986). Despite having no age-related licensing controls, the State of Victoria had no worse older driver crash statistics than other States with established testing programs. Interim results from an update of this study also fail to show any safety benefits for mandatory assessment programs (Langford, study in progress).

Mandatory medical assessment of older drivers to detect those who are unfit to drive has particularly been criticised, since a driver’s health does not necessarily equate to fitness to drive (OECD Expert Group ERS4, in press). When a health problem has been identified, the question of whether to continue driving depends not on a medical diagnosis but rather, on the functional consequences of the illness. And for different people, a given condition may affect fitness to drive in different ways and to different degrees. The expectation that general practitioners can assess all the functional implications may be unrealistic.

Another argument against mandatory testing: it precipitates immobility

If the safety outcomes of mandatory testing are at best, inconclusive, one other outcome is clear. Many drivers voluntarily stop driving rather than undergo mandatory assessment (Levy 1995, Hakamies-Blomqvist and Wahlstrom 1998).
In the State of Queensland, Australia, licence renewal requires a medical assessment once every five years from age 75 onwards. The figure below shows for Queensland, the numbers of drivers who failed a medical assessment for licensing purposes, compared to the numbers who allowed their licences to lapse (Peel 2001).

Figure 2: Number of medical and voluntary surrenders of licence, Queensland, 1998.

The subsequent loss of mobility may be justified if it were limited to unsafe older drivers. With comparative crash data failing to support this outcome, it is more likely that substantial numbers of older drivers are unnecessarily ceasing to drive as a direct result of mandatory testing – a contention that has been supported by an interpretation of the crash data (Lange and McKnight 1996).

LICENSING DEVELOPMENTS IN AUSTRALIA

Given its convenience and relative safety, driving remains the preferred mobility option for older people. At least for the immediate future, the main purpose of any older driver program should be to support continued driving as long as is compatible with specified safety requirements.

(Mobility Needs and Safety Problems of an Ageing Society, Chapter 6: Managing Older Road Users, p1.)

In dismissing mandatory assessment, the OECD Group recognised that licensing jurisdictions retain responsibility for ensuring that licensed drivers are indeed fit to drive. The Group recommended that older driver safety could best be managed by targeting those discernibly at risk, leaving ‘safe’ drivers with the maximum mobility options.

The proposed licensing model for managing older driver safety currently being developed in Australasia (Fildes B et al 2000) complies with the stance taken by the OECD Group.

Advisory committees involving key stakeholders were formed in Australia and New Zealand to work with researchers from the Monash University Accident Research Centre to develop a more effective and acceptable licensing procedure. A number of critical components for the proposed licensing model were identified, including:

- older driver testing to be based on functional ability rather than chronological age;
- development of a network of community referral sources;
- use of multi-tiered assessment procedures and instruments;
- use of a case officer to assist older people through the assessment process;
- use of re-training and rehabilitation procedures where appropriate; and
- expansion of the licensing authority’s role to include counselling on alternative mobility options, whenever appropriate.

Figure 3 shows an outline of the proposed licensing model developed as part of Stage 1 of the project. The origins of the model were based on licensing approaches being in California and Maryland in the USA.

Figure 3 - Outline of the Model Licensing Re-Assessment Procedure for Older Drivers

Community referral, incorporating Level 1 Assessment

The first stage in the model involves the referral of suspected at-risk drivers to licensing authorities for re-assessment. Drivers may be identified in at least the following ways:

- self-referral;
- professional referral, involving health or other professionals, including police;
- community referral, involving any member of the community, including family.

Clear and objective criteria are needed to assist in identifying at-risk drivers. This will reduce subjectivity and will make the referral process more transparent, equitable and acceptable to all involved. Development of assessment instruments is presently underway as part of the project.

For referral based on level 1 assessment to work, it will be essential that in most cases, the older driver has meaningful involvement in any decision to attend the licensing office for further assessment. If referral becomes predominantly ‘tops-down or unilateral, it is likely that both those referring and those referred will reject the process.
The case officer

The case officer is the referred driver’s primary point of contact with the licensing authority and is responsible for progressing each driver through the assessment process from the time of arrival until an outcome is determined. As part of this function, the case officer is to keep each driver fully informed of the assessment process and possible outcomes.

It is inevitable that many older drivers will feel threatened by the assessment process and will need considerable reassurance and guidance if they are to perform to their ability. Particularly, those cases resulting in loss of licence will need to be treated with delicacy and will need the provision of concrete advice regarding other mobility options.

It is anticipated that on other occasions the case officer will also be required to act as an advocate for the driver undergoing assessment. For the model to work, it is critical that drivers be treated with fairness and with due regard to individual circumstances: this might entail the case officer ‘defending’ the driver against particular regulations and procedures. Jurisdictions adopting the proposed model must be prepared to accept this as part of the case officer’s role.

The Screening Process – Level 2 Assessment

Each referred driver will attend the closest licensing office and submit to an initial screening test, conducted by the case officer.

If passed, the licence will be renewed, either unconditionally or for an agreed period only (for example, for a driver with only a marginal pass). Individuals with poor test results will be counselled into surrendering the licence immediately. However, the screening test results will not be the final determinant of licence removal or restriction. Drivers either reluctant to accept counselling advice or who failed only marginally, will be offered further assessment options.

The screening test(s) will need to be brief yet comprehensive, valid and functionally based. The tests currently being evaluated as part of Stage 2 of the Australian licensing project, are largely for perceptual and cognitive competency.

Specialist Referral and Assessment – Level 3A Assessment

Referred drivers may also need to be assessed by medical or other health specialists. The need for specialist assessment may be indicated by:

- the notifying source (eg GP or health service worker);
- the initial medical examination;
- the screening test results.

The case officer will be responsible for directing drivers in these categories to the appropriate specialists.

Specialist assessment will result in one of three major outcomes:
• the driver may be deemed unable to continue to drive safely, in which case the licence will be either cancelled or granted on a restricted basis only;
• the driver may have a temporary condition amenable to treatment, in which case the licence will be suspended until the driver is able to prove fitness to drive;
• the driver may have no discernible medical condition to explain the perceived driving impairment or the poor screening results, in which case an on-road driving assessment will be conducted.

On-road Driving Assessment – Level 3B Assessment

Current driving tests have at best limited success in identifying at-risk drivers. Again, validation of particular tests will be necessary before a final selection is made for inclusion in the proposed licensing model.

On-road testing to be conducted by either the jurisdiction’s testing officers or by specially trained occupational therapists. Assessment at this level will result in one of three outcomes:

• a ‘pass’ driver will continue to hold a driving licence – either indefinitely or depending on the results, may need to be re-assessed after a specified period;
• taking all information into account, the driver may be granted a restricted licence only;
• if justified by the on-road test and perhaps other results, the licence may be cancelled.

Driver Rehabilitation and Re-training

One objective of the model is to allow older drivers to continue driving as long as is compatible with safety considerations. Rehabilitation and re-training options are integral to achieving this and may be invoked at any stage in the assessment process. The options may take many forms, including:

• rehabilitation based upon medical or paramedical treatment of underlying conditions;
• specialised re-training in driving skills (which may include use of special vehicle adaptations), provided by occupational therapists;
• general re-training in driving skills by automobile clubs or by driving schools with appropriately trained instructors.

Following rehabilitation or re-training, drivers would usually be required to again go through the assessment procedures.

The inclusion of rehabilitation and re-training options requires identification of all relevant resources available in each area or jurisdiction. It also requires that case officers be fully informed in this regard and be able to make competent judgements in regard to the suitability of these options for individual drivers.

Appeal procedure and tribunal

It is important for the licensing authority to have an established appeals process for those who feel that they have been inaccurately or unfairly assessed regarding their ability to drive. Further right of review is also available through the Magistrates Court in each jurisdiction.
NEXT STEPS

Stage 2 of the project is currently underway and consists of two major components:

- a process evaluation of the main procedures underpinning the licensing model;
- an evaluation of a number of possible screening tests to be used for level 2 assessment.

Pilot study of the model

The first task in Stage 2 was to evaluate the model’s procedures in a licensing environment, to evaluate their acceptability by both licensing agents and older drivers themselves. The evaluation took place in the State of Tasmania, Australia, where currently older drivers aged 85 years and older are required to undergo annual medical examinations and on-road driving assessment.

Fifty-six older drivers who had already been deemed fit to drive by a medical practitioner, agreed to participate in the study.

When each driver attended the licensing office to complete the required on-road driving test, he or she was met by a case officer who explained the project and the subsequent assessment process to the older driver. Each volunteer then completed a paper and pencil screening test measuring a number of cognitive and physical skills believed to be important for driving. The standard Tasmanian on-road driving test was also re-structured to include an on-road assessment procedure recently introduced in New Zealand specifically for older drivers.

After completing both procedures, participants filled out a questionnaire exploring their level of satisfaction with the new processes.

The results of the questionnaire showed that the majority of participants (96.2% of respondents) stated that they found the model process of licence re-assessment to be acceptable. Almost 98% of respondents indicated that they had found the case officer helpful during the licence re-assessment process - with several using the case officer position as a resource leading up to or following their assessment.

Validation of screening tests.

The notion of an off-road screening test which has the capacity to predict on-road performance and particularly crash involvement, is central to the licensing model. The second component of Stage 2 is to conduct a series of validation studies involving a number of promising screening instruments.

Four tests have been selected for the study:

- the Gross Impairments Screening Battery of General Physical and Mental Abilities (GRIMPS) screening test developed by Scientex, Washington, which was used in the Hobart pilot study;
- the EDS (Elemental Driving Simulator) test developed by Life Science and Associates, New York, which requires participants to undergo a computer-tracking task;
• the CALTEST developed by the Department of Motor Vehicles, California, which is a touch-screen computer test of attention, visual and cognitive abilities. This test was supplemented with a video hazard perception test developed in Victoria, Australia.
• the DriveABLE developed by DriveABLE Inc., Edmonton, Canada, which is a touch-screen computer test of attention, vision and cognitive abilities.

In order to validate these four tests, a randomised control trial commenced in Wellington, New Zealand in February 2001 and will involve some 1500 older drivers. Participants (80 years and older) will consist of drivers who successfully meet the requirements for licence re-assessment in New Zealand. As part of this process they will have undertaken both a medical examination and an on-road-driving test.

Participants are being recruited from licence office records and will complete one of the four tests. They will also complete a survey collecting demographic information, self-reported health status and self-reported crash and infringement history. In addition, the licensing authority will provide official statistics for each participant’s on-road test results, crash history and medical status.

It is expected that a full report on the test validation results will be available in mid-2002.

Stage 3

Subject to the identification of a sufficiently well-performed screening test, it is intended to conduct a full-scale trial of the model in at least one Australasian jurisdiction.

CONCLUSION

Mandatory ‘across-the-board’ assessment of older drivers has at best, limited effectiveness. A targeted approach which focuses on those at heightened risk thereby allowing more intensive assessment where appropriate, appears to be a more efficient means of improving safety for older drivers and other road users.

Australasia’s model re-licensing project has taken the first steps in developing a uniform licensing procedure for Australia and New Zealand. Essential requirements for the proposed model include the establishment of a number of community referral sources for those suspected to be at high risk and the development of accurate and valid instruments to assess safe driving ability. The involvement of general practitioners and other community groups in the process, is seen as critical for the success of the project, as is the provision of re-training and rehabilitation options for some drivers and alternative mobility options for others.

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BUS AND COACH PASSENGER CASUALTIES IN NON-COLLISION INCIDENTS

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Abstract

Two major bus safety reports have recently been completed at ICE. Firstly the ‘Assessment of Passenger Safety in Local Service PSVs’, for the Department of the Environment, Transport and the Regions (DETR), assesses the impact of the Disability Discrimination Act (DDA) and the Disabled Persons Transport Advisory Committee (DIPTAC) regulations on bus travel. Secondly 'Real World Bus and Coach Accident Data from Eight European Countries', for Task 1.1 of the Enhanced Bus and Coach Occupant Safety project (European Commission 5th Framework Project no. 1999-RD.11130), is a collation of European data that identifies the important issues in bus and coach occupant safety. It has become evident during these projects that non-collision incidents are an important part in the injury experience of bus casualties, especially for elderly occupants.

By consideration of both national statistics and in-depth cases a picture has been formed of the bus and coach casualty population and the types of incidents in which these people are injured. These statistics have been presented, along with possible reasons for such a high proportion of casualties occurring in non-collision incidents and recommendations have been made that would lessen the risk of these injuries occurring, through better design and operational changes.

These injuries occur due to a combination of factors. Occupants can fall due to slipping or tripping on poorly designed floor surfaces or in wet weather conditions. Or falls can occur due to acceleration forces as the bus brakes or pulls away. When these falls occur the design of the interior can present an injury risk.

In recent years bus design has changed as a result of new regulations to allow a wider population to use buses, especially with the introduction of low floor access. These features promote easier boarding and alighting and allow less mobile members of the population to make use of bus travel. Unfortunately this may also increase the likelihood of these more vulnerable people receiving injuries on the vehicle.

Many of the issues addressed are particularly relevant to elderly people, small children and their carers.

Keywords: Non-collision, DDA, DIPTAC, PSV, Bus, Coach.

Methodology

This study uses British national road accident data, commonly called 'STATS 19', to investigate bus and coach accidents. The overall criteria for an accident to be included in the records is that a person must have been injured in an accident on a public highway. These accident forms are submitted to the Department of the Environment, Transport and the
Regions (DETR) by each of the 50 police forces in Great Britain.

The authors feel that the level of reporting of injuries to bus and coach occupants in Great Britain is high at all injury levels, due to the responsibility of the driver to report incidents to the operator. There is also a legal obligation to report incidents to the Vehicle Inspectorate. This high level has been evident in the monitoring of police accident reports (received as part of an ongoing injury study) in the Nottinghamshire and Leicestershire counties of Great Britain, from February 2000 to February 2001.

Data are available for Great Britain, which includes England, Scotland and Wales. Whilst a separate vehicle type code is given to buses and coaches unfortunately there is no way to distinguish between a 'city' bus or coach and a 'touring' bus or coach. The analysis therefore covers all buses and coaches that have 17 or more seats (regardless of whether or not they are being used in stage operation).

As part of the study undertaken for the DETR, physical designs of the current bus fleet were examined as part of a market review. This provided information on the types of designs currently in use within the UK and the hazards associated with these designs. A task analysis was undertaken of the actual bus journey from the passengers point of view. This identified the extent of which passengers would be exposed to any hazards during the journey including such things as boarding and alighting. As well as investigating the bus design, passenger issues were considered. These included the effects of sensory disabilities, slips trips and falls and the characteristics of the bus user population. This work has been used in this paper to identify how and why injuries occur.

Results

Overall Picture

This study uses data from 1994 to 1998. The distribution of injury severity, compared to car and taxi, and all road users is given in Table 1, averaged over these five years. Definitions of injury severity are given in the annex.

<table>
<thead>
<tr>
<th>Occupants of:</th>
<th>N° of Vehicles</th>
<th>N° of Casualties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>Buses and Coaches (Passengers)</td>
<td>6,183</td>
<td>19</td>
</tr>
<tr>
<td>Cars (and Taxis)</td>
<td>156,521</td>
<td>1,747</td>
</tr>
<tr>
<td>All Road Users</td>
<td>428,081</td>
<td>3,578</td>
</tr>
</tbody>
</table>

Table 1. Great Britain Casualty Figures (Average 1994 to 1998) (ref. 1)

These figures show that when a passenger is injured in a bus or coach they are less likely to receive a fatal or serious injury than overall road users (7.3% against 14.9%).
Figure 1 gives the overall picture of killed or seriously injured (KSI) road user casualties in Great Britain. Passenger casualties on buses and coaches represent 1.4% of all KSI casualties.

Whilst this percentage is low, and an analysis of exposure indicates that bus travel is one of the safest modes of transport, this study identifies issues that should make local bus transport even safer.

Also, as new low floor buses make travel more viable for less physically mobile passengers it is vitally important to make sure that people are not suffering injuries inside the vehicle which will make the overall proportion of bus casualties higher.

It is also important to look to the future with most governments encouraging the greater use of public transport, especially in congested cities. Recent experience in the UK concerning rail crashes indicates that the public has a keen awareness of the safety of public transport and an expectation of very high levels of safety if they are to use public transport.

**Type of Accident**

![Figure 2. Location of First Impact when Passengers (KSI) are Injured](image1)

![Figure 3. Position / Action of Injured (KSI) Passengers](image2)

Figure 2 shows the location on the vehicle of the first point of impact (left and right are for an occupant sitting in a vehicle facing forward). While this is not necessarily impact direction over the whole national database it is a good estimation of the type of accident.

From figures 2 and 3 it can be seen that 62.6% of all KSI passenger injuries are in non-impact incidents and 57.1% of all KSI passenger casualties are not seated when they are injured. Overall 48.8% of KSI casualties are not seated and the vehicle does not have a collision. These are large proportions of the bus casualty population.

Non-collision incidents typically have a much lower number of casualties per vehicle, 1.14, when at least one injury takes place (the criteria for an accident to be recorded). For frontal damage accidents this figure is 2.05.
KSI Risk

Looking at the severity of injury that occurs when a casualty is not seated it is found that there is a 10.0% likelihood of suffering a KSI injury. This compares to figures of 5.5% for seated passengers and 7.3% overall. More detail is given in figure 4 which covers the whole bus casualty population. All counts given are over the 5 year period.

![Figure 4. Percentage of Casualties Receiving a Serious or Fatal Injury](image)

*If a passenger is struck by a vehicle after safely alighting from a bus or coach they are counted as a pedestrian. If an injury occurs due to a fall onto or off the vehicle they are recorded as boarding or alighting as appropriate.

Interestingly there are more casualties when alighting the vehicle than when boarding, with a shift towards a higher proportion of serious injuries. This could be due to drivers being less aware of these passengers or just the likelihood of falling being greater. Bifocal glasses, that do not give good distance vision when looking down, may also be a problem.

During 5 years of data 39 out of the 93 fatal casualties (42%) occurred when the occupant was standing, boarding or alighting the bus or coach. After looking at some in-depth cases it is apparent that many of these fatal casualties in fact suffered from some kind of fall, trip or slip, whilst standing, alighting or boarding.

Of all casualties that are standing, alighting or boarding, 83.7% are injured in non-collision accidents and it is important to note that 37.5% of seated casualties are also injured in such accidents. For KSI casualties these figures are 85.6% and 22.1%.

Road Classification

Looking at just the non-collision population it is found that 93.9% of all casualties occur on roads with a 30 mph speed limit and 3.6% on 40 mph roads, 93.5% and 4.2% for KSI casualties. This compares to figures of 82.7% and 5.1% for all casualties injured on buses and coaches.

![Figure 5. Casualty Distribution by Road Speed Limit](image)
Roads up to and including 40 mph speed limit are defined as built up areas by the UK government. In the data it is not possible to separate local buses and coaches but this high figure in built up / rural areas indicates that the great majority of non-collision incidents occur on local service buses.

**Other European Countries**

Internationally accident data is collected in slightly different ways but it has been found that the non-collision casualty situations in Austria and Germany broadly mirror Great Britain.

In Austria 32% of all KSI casualties are injured during an emergency braking manoeuvre (ref. 2).

A German in-depth study of city bus accidents, in Bavaria (Munich and Nürnberg), carried out as part of a thesis (ref. 3), revealed that 50% of the casualties in buses are due to non-collision bus accidents. In over 70% of the cases emergency braking was the main cause of the accident in the bus, 72% of these casualties were older than 55 years.

**Who Is Getting Injured?: The Non-Collision Casualty Population**

**Gender and Age**

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 year (1994 to 1998) totals:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male - Fatalities</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Male - Serious</td>
<td>551</td>
<td></td>
</tr>
<tr>
<td>Female - Fatalities</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Female - Serious</td>
<td>1390</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 6. Gender Distribution (KSI)*

Figure 6 gives the gender distribution for KSI casualties, injured when no collision takes place, with the split of 71.6% women and 28.4% men. Seated casualties have been included as the design of the interior can be just as important for them as it is for occupants trying to keep their balance when standing.

The data shows that there are over twice as many females as males. This is likely to be both a function of greater bus use by females and a lower tolerance to injury.

*Figure 7. KSI Casualties By age and gender (per year)*

*Figure 8. KSI Rate Across Age Bands*
Figures 7 and 8 give age distributions for KSI non-collision casualties.

In figure 7 a peak is seen for school age males and there is a very obvious increase in numbers amongst elderly females. The mean age for female casualties is 15 years higher than that for males.

In figure 8 'KSI rate' is used to describe the proportion of all casualties in that group which receive a serious or fatal injury, and it is given as a percentage. Overall there is a marked increase in the likelihood of a serious or fatal injury to a female occupant as their age increases. The increase is most prevalent after the age of 70. The risk of a KSI injury, when an injury has taken place, is lower for young children. For males the pattern is less defined but with the actual numbers being lower.

**Exposure Issues**

Governmental surveys (ref. 4) show that generally women travel more on local buses than men for most types of area and age. This goes some way to explaining why women have a much greater representation as bus or coach casualties than men on the database. Overall it is estimated that in the 16 to 59 years old age group women travel 47% further on local buses than men.

![Graph showing bus journeys by age group](image)

**Figure 9. Share Of Bus Journeys By Age Group NTS 1996-98** (ref. 5)

This figure from the National Travel Survey shows that women of all ages also make more local bus journeys than men, whilst travelling further. This will give women higher exposure to injuries that occur whilst standing, boarding or alighting the vehicle, as they get on and off more often.

**How and Why Do These Injuries Occur?**

This work has shown that 63% of all KSI bus passenger casualties are in non-collision incidents with a shift towards elderly female passengers. This section will discuss problems on buses that cause these injuries. Generally it is felt that most of these types of non-collision injury are taking place on local service buses, borne out by 93.9% of these injuries occurring on 30 mph roads. The rest of this paper will therefore concentrate on these vehicles.
Slips, Trips and Falls on the Vehicle

Caused by:
Slippery floors,
Weather conditions,
Uneven floors,
Unexpected or high steps,
Steep slopes,
Lack of visual cues,
Physiology in the elderly.

Figure 10.       Figure 11.

There are a number of design issues on buses which can cause slips, trips and falls. Floors can be slippery due to inappropriate or worn surfaces. More modern buses have textured floor surfaces which give a good grip but on older buses and especially those which have seen a lot of service, the flooring gets very worn and therefore smoother, which could present a potential slipping hazard.

Weather conditions present many variables which are impossible to remove. Rain, leaves, snow or even wet paper significantly increase the likelihood of an individual slipping on a floor. It is generally recommended that floors should be kept as clean as possible and non slip surfaces should be used throughout.

Uneven floors, especially unpredictable or varying slopes on aisles can present tripping hazards as they are not expected. New guidelines suggest that floors should not have a greater slope than 3 degrees inside the vehicle (figure 10) and 5 degrees around the door area. Buses with internal steps half way down the aisle can cause falls as passengers are busy trying to find an empty seat rather than looking at the floor (figure 11). The height of any steps within the bus should also be consistent.

It is vitally important to mark any steps or floor obstructions on the vehicle to act as visual cues. There should be good marking of steps, good even lighting levels, and appropriate use of colour so passengers can quickly identify grab handles, steps, seats and exits. Steps also wear quickly and become slippery so good maintenance is required.

Generally the elderly are more susceptible to falls and the environment described above will increase the risk of falling. Older persons have stiffer, less co-ordinated and more dangerous gaits than younger persons. Posture control, body-oriented reflexes, muscle strength and tone, and height of step all decrease with age and impair the individual’s ability to avoid a fall after an unexpected trip or when reaching or bending. Age-associated impairment of vision, hearing, and memory also tend to increase the number of trips and stumbles.
Slips, Trips and Falls Whilst Boarding or Alighting

Caused by:
Step to the kerb can be too high,
Riser steps of different heights,
Passengers can be encumbered.

If there is a large initial step when alighting or boarding, or the riser steps are different in height, passengers can lose their balance or misjudge the distance (figure 12). This is especially relevant to the elderly or the encumbered passenger, for example when carrying bags or pushchairs.

Differences in kerb heights at different bus stops is a difficult variable to control but this can exacerbate the problem. All subsequent steps on board the bus should be the same height to avoid loss of balance. A number of alighting cases have resulted in serious injury or even death as people have stumbled and fell under the bus.

Of all KSI non-collision passenger casualties, 38.9% are injured whilst boarding or alighting (Boarding 14.1% Alighting 24.8%). Of these casualties 42.4% occur when the vehicle is stationary and 57.6% when the vehicle is moving.

Boarding and alighting includes passengers being injured while stepping on or off the bus as well as falling over whilst standing as they make their way from or to a seat. This can be seen in the split between casualties when the bus is moving and when it is stationary. National Accident data is collected by individual police officers at the scene of accidents. Therefore there may be some overlap in the understanding of the definitions relating to standing as a passenger and those boarding and alighting.

Operational Issues or Heavy Braking

Falls can occur from the mechanisms mentioned above but the operation of the vehicle can also initiate a fall on a bus.

Caused by:
Acceleration, vehicle pulls away before passenger reaches seat,
Deceleration, passenger stands to get off bus before bus has come to a halt,
Vehicles sometimes need to turn sharply into and out of bus stops,
Emergency manoeuvres.

Due to timetable constraints the bus can often start to accelerate away before passengers, especially the less mobile, have the time to reach a seat or find a place to stand safely and hold on. Passengers can also feel under pressure to stand up before the bus has halted at a bus stop as they fear that they will not be able to get off in time, or the driver may not stop altogether.

Bus stops tend to be recessed which is good for traffic flow but if they are too small the sharp steering motion of entering and exiting bus stops can unbalance passengers.
These factors can cause boarding and alighting passengers to lose balance and fall against rigid parts of the bus interior.

The scenarios above are also relevant to standing passengers who haven't got a seat and 92.3% of standing passenger casualties are injured when the vehicle is moving. Standing passengers account for 39.0% of all KSI non-collision passenger casualties.

The performance of buses in terms of engine power and braking is also improving which can increase the likelihood of injuries occurring due to the operation of vehicles, as they can accelerate and brake more quickly.

Possible solutions:

Occurants must not be standing when the bus is moving.

The vehicle must be smoothly driven with appropriate time-tabling.

The obvious solution to this would be to avoid all standing passengers and ensure that all passengers are seated before the bus moves off from a stop. Likewise, alighting passengers should remain seated until the bus stops. It would be difficult though to not allow standing passengers when the use of public transport and buses is being promoted and operators want to use their vehicles at full capacity when needed.

Another solution would be for the driver to avoid sudden manoeuvres, accelerate and brake more smoothly. However the driver of a modern bus not only has to deal with road conditions and ticket purchases but also has to keep to strict timetables.

Passengers on vehicles also have a duty to reach seats as quickly as possible. Drivers can't be expected to wait if passengers are unnecessarily fussy about where they are sitting!

**Driver Issues**

In work carried out at ICE one operator said 90% of complaints from injured passengers put the blame on the driver. But it is important to recognise workload is high due to:

- high levels of traffic congestion,
- pressure to keep to timetables,
- single operator buses.

Since deregulation in Great Britain there is considerable commercial pressure to keep to timetables due to fierce competition. Also in Britain we are starting to see traffic commissioners banning operators from registering any more services and imposing fines if operators are not running to time (ref. 6). Traffic congestion is much higher so to keep to timetables drivers must not spend too long at bus stops. Also to keep up with modern traffic, bus performance has improved in terms of acceleration and braking, which puts higher forces on any unbalanced passenger.

In addition it is now uncommon to find a separate conductor on a bus, which means that the driver has to deal with tickets, money and any unruly behaviour on the vehicle. This adds to the driver's already stressful working conditions.

The authors would like to see research into the workload of drivers and detailed analysis of the flexibility in bus timetables to examine whether longer stops are in fact an issue in the profitability of the bus service.
Injury Causation

Poor Interior Design

What are the dangers when a passenger does slip, trip or fall? Why are injuries caused?
These pictures give examples of interior design that can lead to injuries when passengers make contact with internal parts of the bus. These are typical of the bus fleet.

![Figure 13.](image1.png)  ![Figure 14.](image2.png)

There are unprotected metal grab rails in the areas where seated passengers’ heads will naturally fall forward and passengers’ upper extremities may hit if they fall over (figures 13 and 14).

![Figure 15.](image3.png)  ![Figure 16.](image4.png)  ![Figure 17.](image5.png)

These pictures show ticket machines with very hard metal edges that a standing passenger could easily fall forwards and hit, for example, during hard braking (figures 15 and 16). Likewise a boarding passenger could trip and strike the machine. Generally ticket machines, card readers, and bins are not integrated into the design of the bus, they appear to be bolted on afterwards depending upon the requirements of the operator. This inevitably causes them to encroach on the standing area.

Also shown is an example of the hard metal joints used for the interior grab bars (figure 17).
Example of a Non-Collision Casualty Case

Here is an example of what the authors feel is a problem with standing passengers, an operational issue and poor interior design.

A 52 year old female passenger stood up on the bus intending to alight at the bus stop shown here (figure 18). She had shopping bags in both hands.

Before reaching the stop a dog ran across the road causing the driver to brake heavily to a halt. Figure 18 shows the bus in the position at which it came to a stop, so it can be seen that the passenger stood up whilst the bus was a good distance from the bus stop. During the braking action of the bus, the passenger fell forwards and received a fatal head injury from the interior contact shown in figure 19.

The shape of the head impact can clearly be seen in the grill with the main injury caused by an impact with the rigid metal surround.

New Legislation

Public Service Vehicles Accessibility Regulations legislate on guidelines from Disability Discrimination Act (DDA), Disabled Persons Transport Advisory Committee (DIPTAC) bus regulations.

Under the Public Service Vehicle Accessibility Regulations which have been in force in the UK since January 2001 the previous guidelines of the Disability Discrimination Act (DDA) have been adopted. These are in line with the European directive on bus safety. Generally these guidelines make access on and off vehicles easier and vehicle interiors safer.

These have significant advantages on the ease of access for all passengers but especially the less mobile. New buses will have low floor access, priority seats and crucially space for wheelchairs and push chairs (figure 20). The improved overall design also includes straight stairs on double-deckers (figure 21), better lighting and better visual marking (figure 22).
Examples of New Design

The Continuing Relevance of Non-Collision Injuries

Even though new legislation has been introduced recently, Great Britain will still have older buses for some time to come and all buses in service will not have to comply until 2015 (Coaches, 2020). In fact in 1999 the average age of the public service vehicle fleet in Great Britain was 10 years old, with 10,000 being up to 18 years old. (ref. 4)

Therefore the authors believe it is very important to still consider the access issues raised in this paper as they will affect bus users for at least another 10 years. Also whilst these access regulations generally improve the interior design of the bus, interior contacts must be kept in mind during the vehicle design.

In fact an unfortunate by-product of some of these regulations is that the number of seats are reduced, which means that more people may be forced to stand or move upstairs, it is therefore just as relevant to consider falls, especially from bus operation, on these new buses as on older buses.

Conclusions

• The majority of killed and seriously injured bus passenger casualties in Great Britain (63%) occur when the vehicle is not involved in a collision.

• It has been found that there is a high proportion of elderly female passengers in this casualty population and when they are injured they have an increased risk of a serious injury.

• Legislation is changing the design of buses and the authors obviously support those changes which make public transport more widely available. However legislation is improving access for all, enabling more extremes of the population and therefore the less mobile, to travel on buses. These people will be both more susceptible to falls, and to injuries if they fall, whilst on the vehicle.

• New regulations are in force but they do not place requirements on good operating practice, also the vehicle fleet includes a large proportion of older vehicles and these new bus designs will not be commonplace for many years to come.
**Recommendations**

- Regulations have improved access but better interior design is needed, especially around the ticket/driver area and near to the doors to minimise contact injuries. Maintenance procedures should also ensure there is no compromise on safety.
- There should be less pressure on operators and therefore drivers to achieve stricter timetables in mounting congestion.
- Systems need to be in place to ensure that drivers are aware that a seated passenger wishes to alight at the next stop, and passengers need reassurance that the driver is aware they wish to alight. Bell pushes to achieve this should be in easy reach of all passengers.
- During busy times on busy routes it would be beneficial to have a conductor accompanying the driver, collecting fares, helping passengers (especially with wheelchairs) and dealing with unruly passengers, leaving the driver to concentrate on driving.

**References**

2. Technical University Graz, Austria, ECBOS report Task 1.1. [www.dsd.at/ecbos.htm](http://www.dsd.at/ecbos.htm)
6. Coach and Bus Week Magazine, published by Emap Automotive. [www.cbwnet.co.uk](http://www.cbwnet.co.uk)

**General References:**

- Reports for Task 1.1 of the Enhanced Bus and Coach Occupant Safety project (European Commission 5th Framework Project no. 1999-RD.11130) [www.dsd.at/ecbos.htm](http://www.dsd.at/ecbos.htm)

National STATS 19 road accident data is collated by the Department of the Environment, Transport and the Regions and supplied to the Vehicle Safety Research Centre in electronic form by the UK Data Archive at Essex University.

Now the Department for Transport, Local Government and the Regions (DTLR).
ANNEX

UK Definitions of Injury Severity

Fatal Injury
Fatal injury includes only those cases where death occurs in less than 30 days as a result of the accident. 'Fatal' does not include death from natural causes or suicide.

Serious Injury
Hospital in-patient.
Examples of 'Serious' injury are:

- Fracture,
- Internal injury,
- Severe cuts and lacerations,
- Crushing,
- Concussion,
- Severe general shock requiring hospital treatment,
- Detention in hospital as an in-patient, either immediately or after,
- Injuries to casualties who die 30 or more days after the accident from injuries sustained in that accident.

Slight Injury
Receive or appear to need medical treatment.
Examples of 'Slight' injury are:

- Sprains,
- Cuts judged not to be severe,
- Slight shock requiring roadside attention.

(Persons who are merely shaken and who have no other injury are not included unless they receive or appear to need medical treatment).
1. Introduction

Road safety in urban areas is considered to be one of the major problems our society face nowadays due to its social and economical impacts. Statistics show that accidents in urban areas are about 50% of the total road accidents in the E.U. The problem is more crucial when considering the case of the vulnerable road users (e.g., pedestrians and motorcyclists). In France, pedestrian fatalities represented 21% of all traffic fatalities in 1970 and 12% in 1995 [1]. Problems appear to be harder for the children and the elderly pedestrians. The annual pedestrian fatality rate in Seattle, WA, U.S.A. [2] averaged 2/100,000 for all ages and both sexes and the age-specific rate varied between 1/100,000 for the 22-34 year age group to 1.5/100,000 for children under seven years and 7/100,000 for the ages 70 years and older. In a survey which was carried out in Sussex [3] among elderly pedestrians who had been involved in road accidents, 63% said that they did not see the striking vehicle before it hit them. In New Zealand the mortality rate for motorcyclists is 3.5 per 100,000 persons per year or 9.6 per 10,000 registered motorcycles and is considered as high in comparison with the rate in other countries as for example Great Britain where the respective rate was approximately 1.41 per 100,000 of population [4]. The road accident data concerning E.U., U.S.A. and Canada for the year 1997 is presented in Tables 1 (Persons killed including vulnerable road users) and 2 (Persons injured including vulnerable road users).

As shown in Table 1 the pedestrians killed expressed as a percentage of the total persons killed in road accidents are in the area of 10.4% (Belgium) to 27.5% (Ireland) for the E.U. countries while the respective percentage in U.S.A. is 12.6% and in Canada is 13.1%. The respective figures concerning cycles in E.U. are between 1.7% (Luxemburg) and 20.8% (Netherlands), 1.9% in the U.S.A. and 2.2% in Canada. The respective figures concerning mopeds in E.U. are between 0.5% (U.K.) and 17.4% (Portugal), 0.05% in the U.S.A. and 3.9% in Canada. Finally, the respective figures concerning motorcycles in E.U. are between 1.8% (Finland) and 13.7% (U.K.), and 5% in the U.S.A. No direct comparisons can be made since the number and use of cycles, mopeds and motorcycles varies between countries. In all E.U. countries a number of 1,237,176 accidents took place involving personal injury, while 41,737 is the total number of persons killed in the year 1997. The total number of pedestrians killed in E.U. (Greece is excluded) is 6,049 in the same year. The percentage of the pedestrians killed in E.U. (with the exception of Greece) is 15.3% of the total persons killed in road accidents.
Table 1: Persons Killed in E.U, U.S.A and Canada (year 1997)

<table>
<thead>
<tr>
<th>Country</th>
<th>Accidents involving personal injury</th>
<th>Total persons killed</th>
<th>Pedestrians killed / (% of the total persons killed)</th>
<th>Cycles / (% of the total persons killed)</th>
<th>Mopeds / (% of the total persons killed)</th>
<th>Motorcycles / (% of the total persons killed)</th>
<th>Car Passenger / (% of the total persons killed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>39,695</td>
<td>1,105</td>
<td>156/ 14,1%</td>
<td>66/ 6%</td>
<td>58/ 5,2%</td>
<td>111/ 10%</td>
<td>666/ 60,3%</td>
</tr>
<tr>
<td>Belgium</td>
<td>50,078</td>
<td>1,364</td>
<td>142/ 10,4%</td>
<td>122/ 8,9%</td>
<td>68/ 5%</td>
<td>125/ 9,2%</td>
<td>844/ 61,9%</td>
</tr>
<tr>
<td>Denmark</td>
<td>8,004</td>
<td>489</td>
<td>87/ 17,8%</td>
<td>65/ 13,3%</td>
<td>23/ 4,7%</td>
<td>23/ 4,7%</td>
<td>259/ 53%</td>
</tr>
<tr>
<td>Finland</td>
<td>6,980</td>
<td>438</td>
<td>69/ 15,7%</td>
<td>61/ 13,9%</td>
<td>16/ 3,6%</td>
<td>8/ 1,8%</td>
<td>247/ 56,4%</td>
</tr>
<tr>
<td>France</td>
<td>125,202</td>
<td>7,989</td>
<td>929/ 11,6%</td>
<td>329/ 4,1%</td>
<td>471/ 5,9%</td>
<td>831/ 10,4%</td>
<td>5,069/ 63,4%</td>
</tr>
<tr>
<td>Germany</td>
<td>380,835</td>
<td>8,549</td>
<td>1,147/ 13,4%</td>
<td>679/ 7,9%</td>
<td>169/ 2%</td>
<td>974/ 11,39%</td>
<td>5,249/ 61,4%</td>
</tr>
<tr>
<td>Greece</td>
<td>24,319</td>
<td>2,199</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>8,496</td>
<td>472</td>
<td>130/ 27,5%</td>
<td>24/ 5,1%</td>
<td>68/ 14,4%</td>
<td>(a)</td>
<td>219/ 46,4%</td>
</tr>
<tr>
<td>Italy</td>
<td>190,031</td>
<td>6,226</td>
<td>828/ 13,2%</td>
<td>397/ 6,4%</td>
<td>651/ 10,5%</td>
<td>482/ 7,7%</td>
<td>3,454/ 55,5%</td>
</tr>
<tr>
<td>Luxemburg</td>
<td>1,016</td>
<td>60</td>
<td>8/ 13,3%</td>
<td>1/ 1,7%</td>
<td>1/ 1,7%</td>
<td>2/ 3,4%</td>
<td>46/ 76,7%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>11,238</td>
<td>1,163</td>
<td>119/ 10,23%</td>
<td>242/ 20,8%</td>
<td>88/ 7,6%</td>
<td>92/ 7,9%</td>
<td>547/ 47%</td>
</tr>
<tr>
<td>Portugal</td>
<td>49,417</td>
<td>1,939</td>
<td>422/ 21,8%</td>
<td>58/ 3%</td>
<td>338/ 17,4%</td>
<td>185/ 9,5%</td>
<td>766/ 39,5%</td>
</tr>
<tr>
<td>Spain</td>
<td>86,067</td>
<td>5,604</td>
<td>967/ 17,2%</td>
<td>116/ 2,1%</td>
<td>440/ 7,8%</td>
<td>466/ 8,2%</td>
<td>2,993/ 53,4%</td>
</tr>
<tr>
<td>Sweden</td>
<td>15,752</td>
<td>541</td>
<td>72/ 13,3%</td>
<td>42/ 7,8%</td>
<td>13/ 2,45</td>
<td>36/ 6,7%</td>
<td>348/ 64,3%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>240,046</td>
<td>3,599</td>
<td>973/ 27%</td>
<td>183/ 5,1%</td>
<td>17/ 0,5%</td>
<td>492/ 13,7%</td>
<td>1,795/ 49,9%</td>
</tr>
<tr>
<td>U.S.A</td>
<td>2,222,000</td>
<td>41,967</td>
<td>5,307/ 12,6%</td>
<td>813/ 1,9%</td>
<td>22/ 0,05%</td>
<td>2,084/ 5%</td>
<td>21,989/ 52,4%</td>
</tr>
<tr>
<td>Canada</td>
<td>152,689</td>
<td>3,064</td>
<td>403/ 13,1%</td>
<td>67/ 2,2%</td>
<td>120/ 3,9%</td>
<td>(a)</td>
<td>2,391/ 78%</td>
</tr>
</tbody>
</table>

(a) included under the previous item

Source: [5]

Table 2: Persons Injured in E.U, U.S.A and Canada (year 1997)

<table>
<thead>
<tr>
<th>Country</th>
<th>Total persons injured</th>
<th>Pedestrians injured / (% of the total persons injured)</th>
<th>Cycles / (% of the total persons injured)</th>
<th>Mopeds / (% of the total persons injured)</th>
<th>Motorcycles / (% of the total persons injured)</th>
<th>Car Passenger / (% of the total persons injured)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>51,591</td>
<td>4,542/ 8,8%</td>
<td>5,614/ 10,8%</td>
<td>4,205/ 8,1%</td>
<td>2,914/ 5,6%</td>
<td>31,864/ 61,8%</td>
</tr>
<tr>
<td>Belgium</td>
<td>69,543</td>
<td>3,890/ 5,6%</td>
<td>7,297/ 10,5%</td>
<td>7,312/ 10,5%</td>
<td>3,359/ 4,8%</td>
<td>44,350/ 63,8%</td>
</tr>
<tr>
<td>Denmark</td>
<td>9,617</td>
<td>922/ 9,6%</td>
<td>2,088/ 21,7%</td>
<td>679/ 7,1%</td>
<td>608/ 6,3%</td>
<td>4,571/ 47,5%</td>
</tr>
<tr>
<td>Finland</td>
<td>8,957</td>
<td>952/ 10,6%</td>
<td>1,279/ 14,3%</td>
<td>466/ 5,2%</td>
<td>391/ 4,3%</td>
<td>5,229/ 58,4%</td>
</tr>
<tr>
<td>France</td>
<td>169,578</td>
<td>19,152/ 11,3%</td>
<td>7,191/ 4,2%</td>
<td>20,526/ 12,1%</td>
<td>18,066/ 10,6%</td>
<td>98,259/ 57,9%</td>
</tr>
<tr>
<td>Germany</td>
<td>501,094</td>
<td>39,738/ 7,9%</td>
<td>71,988/ 14,4%</td>
<td>17,796/ 3,6%</td>
<td>41,226/ 8,2%</td>
<td>308,184/ 61,5%</td>
</tr>
<tr>
<td>Greece</td>
<td>32,667</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ireland</td>
<td>13,115</td>
<td>1,629/ 12,4%</td>
<td>652/ 5%</td>
<td>1,214/ 9,3%</td>
<td>(a)</td>
<td>8,346/ 63,6%</td>
</tr>
<tr>
<td>Italy</td>
<td>270,962</td>
<td>15,502/ 5,7%</td>
<td>9,156/ 3,4%</td>
<td>49,478/ 18,3%</td>
<td>17,133/ 6,3%</td>
<td>167,117/ 61,7%</td>
</tr>
<tr>
<td>Luxemburg</td>
<td>1,498</td>
<td>133/ 8,9%</td>
<td>32/ 2,1%</td>
<td>10/ 0,7%</td>
<td>79/ 5,3%</td>
<td>1,099/ 73,4%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>11,718</td>
<td>855/ 7,3%</td>
<td>2,518/ 21,5%</td>
<td>2,187/ 18,7%</td>
<td>880/ 7,5%</td>
<td>4,749/ 40,5%</td>
</tr>
<tr>
<td>Portugal</td>
<td>66,516</td>
<td>9,189/ 13,8%</td>
<td>1,556/ 2,3%</td>
<td>14,615/ 22%</td>
<td>5,026/ 7,6%</td>
<td>30,632/ 46%</td>
</tr>
<tr>
<td>Spain</td>
<td>125,247</td>
<td>12,777/ 10,2%</td>
<td>2,527/ 2%</td>
<td>20,425/ 16,3%</td>
<td>11,779/ 9,4%</td>
<td>67,095/ 53,6%</td>
</tr>
<tr>
<td>Sweden</td>
<td>21,280</td>
<td>1,312/ 6,2%</td>
<td>3,142/ 14,8%</td>
<td>756/ 3,5%</td>
<td>852/ 4%</td>
<td>13,934/ 65,5%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>323,945</td>
<td>44,558/ 13,7%</td>
<td>24,402/ 7,5%</td>
<td>2,201/ 0,7%</td>
<td>21,710/ 6,7%</td>
<td>209,597/ 64,7%</td>
</tr>
<tr>
<td>U.S.A</td>
<td>3,400,000</td>
<td>78,000/ 2,3%</td>
<td>58,000/ 0,02%</td>
<td>3,000/ 0,09%</td>
<td>51,000/ 1,5%</td>
<td>2,379,000/ 70%</td>
</tr>
<tr>
<td>Canada</td>
<td>221,186</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

(a) included under the previous item

Source: [5]
2. Evolution of Traffic Accidents with Vulnerable Road Users in Greece

Accidents involving pedestrians in Greece for the period 1981-95 represents the 22% of the total number of road accidents for the same period. The percentage of pedestrians killed or injured represents the 13% of the total number of persons killed or injured in the country within the examined period [6]. Most of the accidents involving pedestrians concerns either children (0-14 years) or elder people (45-64, 65+) while almost 90% of the accidents take place in urban areas [7]. Especially for the pedestrians, their involvement in road accidents implies high possibility of death or severe injury. From the analysis of the accidents involving pedestrians in Greece for the period 1981-1991 it resulted that the number of deaths per 100 of casualties increased during the examined decade. Among the main reasons for the involvement of pedestrians in road accidents is the relatively poor infrastructure for their protection (e.g., pedestrian crossings, pedestrian streets etc.) together with the aggressive driving behavior. From the pedestrian accident data analysis in a number of 25 intersections in Thessaloniki for the period 1990-92 it was found that the most important parameters which influence a pedestrian accident is the type of intersection, the lighting conditions, the pedestrian and vehicle flow as well as the traffic composition and the geometric characteristics of the intersection [8]. Concerning the accidents with motorcycle involvement it was found in a research undertaken by the University of Thessaloniki in Northern Greece that in 76% of all cases the drivers were not wearing a protective helmet [9]. The evolution of road accidents in Greece for the period 1993-96 and the evolution of vulnerable road users accidents in Greece during the period 1994-96 is presented in Tables 3 and 4 respectively.

Table 3: Evolution of Road Accidents in Greece for the period 1993-96

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of accidents</td>
<td>23.892</td>
<td>18.469</td>
<td>12.685</td>
</tr>
<tr>
<td>Accidents including fatalities</td>
<td>1,833</td>
<td>1,701</td>
<td>1,009</td>
</tr>
<tr>
<td>Accidents including severe injuries</td>
<td>2,437</td>
<td>2,364</td>
<td>1,471</td>
</tr>
<tr>
<td>Accidents including light injuries</td>
<td>19,622</td>
<td>14,404</td>
<td>10,205</td>
</tr>
<tr>
<td>Total number of fatalities and injuries</td>
<td>34,135</td>
<td>25,354</td>
<td>16,476</td>
</tr>
<tr>
<td>Number of fatalities</td>
<td>2,076</td>
<td>1,929</td>
<td>1,113</td>
</tr>
<tr>
<td>Number of severe injuries</td>
<td>3,387</td>
<td>3,274</td>
<td>1,888</td>
</tr>
<tr>
<td>Number of light injuries</td>
<td>28,672</td>
<td>20,151</td>
<td>13,475</td>
</tr>
<tr>
<td>VRU casualties</td>
<td>3,275</td>
<td>3,269</td>
<td>1,764</td>
</tr>
<tr>
<td>VRU fatalities</td>
<td>909</td>
<td>956</td>
<td>529</td>
</tr>
<tr>
<td>VRU severe injuries</td>
<td>1,965</td>
<td>1,948</td>
<td>1,051</td>
</tr>
<tr>
<td>VRU light injuries</td>
<td>401</td>
<td>365</td>
<td>184</td>
</tr>
<tr>
<td>Two wheeler casualties</td>
<td>2,289</td>
<td>2,317</td>
<td>1,227</td>
</tr>
<tr>
<td>Two wheeler fatalities</td>
<td>484</td>
<td>531</td>
<td>280</td>
</tr>
<tr>
<td>Two wheeler severe injuries</td>
<td>1,453</td>
<td>1,452</td>
<td>772</td>
</tr>
<tr>
<td>Two wheeler light injuries</td>
<td>352</td>
<td>334</td>
<td>175</td>
</tr>
<tr>
<td>VRU casualties / Total number of fatalities and injuries</td>
<td>0,096</td>
<td>0,129</td>
<td>0,107</td>
</tr>
<tr>
<td>VRU fatalities / Number of fatalities</td>
<td>0,438</td>
<td>0,496</td>
<td>0,475</td>
</tr>
<tr>
<td>VRU severe injuries / Number of severe injuries</td>
<td>0,580</td>
<td>0,595</td>
<td>0,557</td>
</tr>
<tr>
<td>VRU light injuries / Number of light injuries</td>
<td>0,014</td>
<td>0,018</td>
<td>0,014</td>
</tr>
<tr>
<td>Two wheeler casualties / Total number of fatalities and injuries</td>
<td>0,067</td>
<td>0,091</td>
<td>0,075</td>
</tr>
<tr>
<td>Two wheeler fatalities / Number of fatalities</td>
<td>0,233</td>
<td>0,275</td>
<td>0,251</td>
</tr>
<tr>
<td>Two wheeler severe injuries / Number of severe injuries</td>
<td>0,429</td>
<td>0,444</td>
<td>0,409</td>
</tr>
<tr>
<td>Two wheeler light injuries / Number of light injuries</td>
<td>0,012</td>
<td>0,017</td>
<td>0,013</td>
</tr>
</tbody>
</table>

VRU: Vulnerable Road Users
Source: [10]

Considering the accident involvement by type of motorcycle engine in Greece for the period 1985-93, the type [ 50cc (mopeds) appear to have the smaller accident index (3,67/1.000 motorcycles) but they
contribute to more than 50% to the total number of two-wheel accidents [11]. The risk of death for the ages up to 34 years increases as the power capacity of the motorcycle increases while for ages >34 years the risk decreases as the power capacity of the motorcycle increases [12].

According to the results of an extensive survey on traffic safety in the Athens Metropolitan Area (A.M.A.) 29,277 road accidents took place during the period 1992-94, of which 3,019 accidents included killed or injured persons [13]. As a result of these accidents 1,308 persons were killed and 2,292 were seriously injured. One third of the total number of road accidents took place in road sections while the rest two thirds took place at intersections. There were 6,186 road accidents involving pedestrians (21% of the total number of accidents) of which 958 led to fatalities or severe injuries.

Within the framework of the General Transportation Study of the Thessaloniki Metropolitan Area (T.M.A.) which was carried out in the period 1998-99 [14] an extensive survey on road accidents took place. In Table 5 the general results of this survey for eleven municipalities are presented. As shown in this Table, the percentage of accidents involving pedestrians is 19.3% (all eleven municipalities).

Especially for the municipality of Thessaloniki, which actually is the biggest municipality in terms of area and population in T.M.A., the respective percentage is in the area of 22% for the period 1993-96. Within only the boundaries of the municipality of Thessaloniki, the accidents involving pedestrians for the same period represent the 71.3% of the total number of the specific type of accidents in the eleven Municipalities (1321 out of 2104 accidents) and the 57.1% of the pedestrians killed. It must be mentioned at this point that the respective percentage for the total number of accidents is 62.8%.

Generally, one out of five accidents concerns the pedestrians in the examined area of the eleven municipalities. There are major arterial streets in the city which are characterized by an excessive number of pedestrian accidents like Konstantinoupolioes in the Municipality of Stavrourpouli where the 70.5% of all pedestrian accidents occurred in the Municipality took place in this specific road [15].

3. Measures for the Protection of Vulnerable Road Users

As commonly expected, the provision of the adequate infrastructure for the pedestrians and cyclists has a great influence on the number of this specific category of accidents. According to a survey in Great Britain [16] a reduction of 18% in the total number of accidents occurred between the 3-year period before and after the introduction of crossing facilities at 16 zebra crossings, 22 pelican crossings and 19 refuges.

Many authorities at national, regional and local level have implemented specific measures in order to reduce the number of accidents, putting emphasis on the case of vulnerable road users (e.g., in school areas). Especially, during the last decade, a significant number of studies concerning road safety took place in Greece, and as a result traffic calming measures (e.g., speed reduction measures) were implemented.

As a result of the traffic accident survey in A.M.A [13], a number of proposals have been made to the authorities concerning measures for the improvement of safety level and emphasis was put on the protection of the pedestrians (e.g., traffic signal installations, parking prohibitions, proper signing, construction of barriers at sidewalks, removal of bus stops from improper places etc.). Also in T.M.A. emphasis was given to the improvement of safety level in “black spots” (spots with high concentration of road accidents). In some cases pedestrianizations schemes were implemented in various Municipalities in T.M.A., but not in major arterial streets, and thus the effect on the safety level for the pedestrians was limited [17].
### Table 4: Evolution of Vulnerable Road Users Accidents in Greece during the period 1994-96

<table>
<thead>
<tr>
<th></th>
<th>Accidents with pedestrians</th>
<th>Accidents with bicyclists</th>
<th>Accidents with motorcyclists</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F (1) %</td>
<td>S.I (2) %</td>
<td>L.I (3) %</td>
<td>F %</td>
</tr>
<tr>
<td>1994</td>
<td>425 25.95</td>
<td>512 16.12</td>
<td>49 1.67</td>
<td>15 0.92</td>
</tr>
<tr>
<td>1995</td>
<td>425 22.03</td>
<td>497 15.18</td>
<td>31 0.98</td>
<td>19 0.46</td>
</tr>
<tr>
<td>1996 (4)</td>
<td>249 22.37</td>
<td>279 14.78</td>
<td>9 1.21</td>
<td>9 0.03</td>
</tr>
</tbody>
</table>

(1) F: Fatal accidents, (2) S.I: accidents involving severe injuries, (3) L.I: accidents involving light injuries, (4) Data for seven months (January-July)

Source: [10]

### Table 5: Evolution of Road Accidents in Thessaloniki Metropolitan Area during the period 1993-96

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total no. of accid.</td>
<td>Pedestr. accid.</td>
<td>No. of deaths</td>
<td>Total no. of accid.</td>
<td>Pedestr. accid.</td>
<td>No. of deaths</td>
</tr>
<tr>
<td>Thessaloniki</td>
<td>373 77 7</td>
<td>372 73 11</td>
<td>318 81 11</td>
<td>258 58 3</td>
<td>619</td>
<td>1321</td>
</tr>
<tr>
<td>Kalamaria</td>
<td>68 9 2</td>
<td>67 7 2</td>
<td>58 8 2</td>
<td>43 8 0</td>
<td>147</td>
<td>236</td>
</tr>
<tr>
<td>Ampelokipi</td>
<td>24 2 0</td>
<td>16 3 0</td>
<td>24 3 0</td>
<td>27 2 0</td>
<td>55</td>
<td>91</td>
</tr>
<tr>
<td>Eleftherio-Kordelio</td>
<td>13 4 1</td>
<td>5 1 0</td>
<td>17 1 1</td>
<td>12 0 1</td>
<td>31</td>
<td>47</td>
</tr>
<tr>
<td>Evosmos</td>
<td>28 3 3</td>
<td>24 1 0</td>
<td>17 4 1</td>
<td>13 3 0</td>
<td>59</td>
<td>82</td>
</tr>
<tr>
<td>Menemeni</td>
<td>16 1 0</td>
<td>8 2 0</td>
<td>12 3 0</td>
<td>4 0 0</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>Neapoli</td>
<td>13 2 1</td>
<td>14 6 0</td>
<td>19 0 2</td>
<td>19 4 0</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>Pilea</td>
<td>9 0 1</td>
<td>0 0 0</td>
<td>4 2 0</td>
<td>1 0 0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Stavroupoli</td>
<td>41 9 0</td>
<td>37 8 3</td>
<td>45 4 2</td>
<td>23 5 0</td>
<td>89</td>
<td>146</td>
</tr>
<tr>
<td>Polihnii</td>
<td>9 0 1</td>
<td>11 3 0</td>
<td>3 0 0</td>
<td>7 1 1</td>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>Sikies</td>
<td>14 3 0</td>
<td>12 2 1</td>
<td>5 1 0</td>
<td>1 0 0</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>608 111 15</td>
<td>566 106 17</td>
<td>522 107 19</td>
<td>408 81 5</td>
<td>1130</td>
<td>2104</td>
</tr>
<tr>
<td>%</td>
<td>18.3</td>
<td>18.7</td>
<td>20.5</td>
<td>19.9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: [14]
Police enforcement also plays an important role in the effort to reduce the number of road accidents. According to the police records [18] in A.M.A. there were 500,422 Highway Code violations recorded by the police (of which 178,100 speed limit violations) during the first seven months of the year 2001 while the respective number for the year 2000 was 286,057 (of which 86,486 speed limit violations). According to these figures there is an enormous increase in the number of Highway Code violations from year 2000 to 2001 in the examined area. Helicopters and radars are used in order to assist police effort for the supervision of the road network and also alcohol tests are performed very often.

Among the basic actions in order to improve the safety level in the country is the operation of candidates and tactical drivers’ training and examination centers. An extensive research has been recently made in Greece [19,20] aiming at the design and operation of such centers in order to provide all the necessary facilities for the proper training and examination of candidates and tactical drivers (motorcycle drivers included). This effort was initiated by the Ministry of Transport and Communications and nowadays a prototype center has been designed and its feasibility study was performed for the city of Serres in Northern Greece [21]. The same Ministry established the National Committee for Road Safety in 1999 and it designed the National Program for Road Safety. It must also be mentioned that the National Technical University of Athens is responsible for the development of a Strategic Plan for the improvement of road safety in Greece, 2001-2005 [22].

4. Discussion

Accidents involving pedestrians in Greece represent the 22% of the total number of road accidents while the percentage of pedestrians killed or injured represents the 13% of the total number of persons killed or injured. In Athens Metropolitan Area 21% of the total number of accidents refer to pedestrian accidents while in Thessaloniki Metropolitan Area the respective percentage is in the area of 22%. Accidents involving motorcycles represent about 40% of all road accidents. Specific measures in order to reduce the number of accidents were taken by the authorities and a significant number of studies concerning road safety took place in the country during the last decade. Emphasis is put on all three components of road safety (drivers, vehicles, road). Since the majority of pedestrian accidents take place at major arterial streets, priority must also be put to improve the safety level at these road sections. The establishment of the National Committee for Road Safety in 1999 was a basic step towards the overall improvement of the safety level in the country.

References

Modelling Pedestrians’ Crossing Behavior: Some Empirical Evidence

by

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Abstract

This paper presents a methodology for studying pedestrians’ behavior at pedestrian crossings. The developed mathematical models are empirically tested using pedestrian data collected at a number of pedestrians crossings in Amman. Estimated models include waiting time at the curbside and the number of crossing attempts needed by the pedestrian to make a successful crossing. From a broad range of road user and roadway factors, the strongest and most significant predictors which influenced the pedestrian’s waiting time (delay) and the frequency of attempts to cross the streets were gender, age, number of children in household, crossing frequency, number of people in the group attempting to cross, access to private vehicle, destination, home location in relation to pedestrian crossing, and pedestrian past involvement in traffic accidents. In addition to these predictors, maximum likelihood estimates revealed that the pedestrian expected waiting time seems to profoundly influence the number of attempts needed to successfully cross the street.
1. Introduction

Studies concerning accidents involving pedestrians have addressed a number of essential issues. These issues include delay at pedestrian crossings (see Griffiths et al. (1984)), drivers and pedestrians behavior and interaction at pedestrian crossings (see Varhelyi (1998), Katz et al. (1975), Himanen and Kulmala (1988), Song et al. (1993), Cresswell and Hunt (1979), Griffiths et al. (1976), Fegan (1978), Landles (1983)). A number of factors have been considered in these studies including: factors relating to physical environment (e.g. road width, existence of a central refuge at the crossing), road user variables (e.g. age, gender, socioeconomic characteristics, marital status), and the number of pedestrians in the group attempting to cross. Some of these factors turned out to influence the pedestrian’s decision to cross the roadway.

Griffiths et al. (1984) developed models that describe delays at sites without a central refuge and with effectively a single stream of vehicles in each direction. The paper addressed the issue of delay at pedestrian crossings where the major source of delay is attributed to the interaction between vehicles and pedestrians. The study reported that most drivers were prepared to stop when a pedestrian occupied or was approaching their part of the roadway. Young children and elderly pedestrians were likely to step onto the roadway when it was clear that a driver had yielded right of way or if the road was clear of approaching vehicles. The study indicated that as vehicle delay increases, drivers become more aggressive, taking advantage of very small gaps, in pedestrian flow across the pedestrian crossing. Katz et al. (1975) reported that drivers slowed or gave the right of way more often for crossing pedestrians as a group, rather than as an individual.

Himanen and Kulmala (1988) specified and estimated a discrete choice model aiming to study the encounters between drivers and pedestrians at pedestrian crossings. The study addressed the problem by considering the prevailing choices of both drivers and pedestrians. Taking a variety of pedestrian’s, environmental, and traffic conditions into consideration, the probabilities of a driver braking or weaving and of a pedestrian continuing to cross in response to an encounter were identified. The data were collected through a video camera, as such, information relating to pedestrian’s type of trip in pursuit and socioeconomic characteristics were not gathered. The study reported that safety margins exists when the speed of the approaching vehicle is low. For example, if the speed of the vehicle 20m prior to the pedestrian crossing is 50kmph, there is no safety margin in the encounter. The study indicated that the most
important explanatory variables were, number of pedestrians in the group, city size, vehicle speed, vehicle platoon size, and pedestrian distance from curb.

In Jordan, drivers’ inclination to slow down and give way to pedestrians at pedestrian crossings is very low. Pedestrians usually wait at the curbside with the knowledge that drivers are not willing to stop and give them the right of way. As such, they try to force their way across hoping that drivers will slow or stop. This crossing paradigm is likely to increase the pedestrians’ waiting time (delay) and therefore the potential for pedestrian accident involvement is increased. In making recommendations to reduce pedestrian accidents it is essential to study behavioral aspects of pedestrians at pedestrian crossings.

In this paper, the pedestrian’s waiting time (delay) at the curbside is modeled by the risk function. If a pedestrian attempted to cross the road and was successful then this means that the waiting time at the curbside has ceased. If on the other hand the attempt was not successful, then the waiting time has not ceased and the pedestrian has to make more attempt(s) to cross the road. It is hypothesized in this paper that as the number of crossing attempts increase, pedestrians in turn are likely to be bold and thereby force approaching vehicles to brake (i.e. increase the risk of crossing).

2. Data Collection

In Jordan, the inclination of drivers to give way to pedestrians at pedestrian crossings is very low. According to 1997 figures, pedestrian accidents accounted for 15% of the total accidents in Jordan. In addition, 35% of total traffic-related injuries and 42% of traffic-related fatalities involved pedestrians. In the capital city of Amman, 54% of fatalities (all fatalities resulting from all types of accidents) are attributed to pedestrian accidents. Moreover, 52% of pedestrian accidents causation is due to drivers not yielding the right-of-way to pedestrians.

Pedestrians attempting to cross pedestrian crossings were observed at ten mid-block pedestrian crossings located in urban settings with level terrain in Amman. The crossings were selected provided that an approaching driver would be able to observe a pedestrian at the pedestrian crossing well in advance. At pedestrian crossings, each pedestrian was monitored from the time he/she arrived at the crossing until he/she had successfully crossed the street. The arrival and the departure time (time the pedestrian stepped off the curb with the intention of crossing) for each pedestrian were recorded. The waiting time for each pedestrian was taken as the difference between these two times (curbside delay). The pedestrian monitoring process was
discrete in order not to influence pedestrian behavior at the pedestrian crossing. Once the pedestrian had successfully crossed, he/she was asked a set of questions.

3- Model Formulation

3.1 Pedestrians’ waiting time (delay)

The distribution of pedestrians’ waiting time (t) on pedestrian crossing, considered as a random variable, is characterized in this paper by the risk function $\xi(t)$. This risk function gives the instantaneous failure rate (ending the waiting time at the curbside) if the pedestrian has not crossed successfully the street to time t. The pedestrian’s waiting time is assumed to depend on exogenous variables. As such, the risk function can be stated as,

$$
\xi(t|R) \equiv \lim_{\Delta t \downarrow 0} \Pr[T \leq t + \Delta t, T \geq t | R]
$$

where $R$ is a column vector of exogenous variables. Since all pedestrians were observed to complete the duration of crossing, observations are said to be non-censored. The probability density function ($f(t)$) can be stated as (see Andersen (1991)),

$$
\Phi(t) = \xi(t|R) \exp\left[\int_0^t \xi(s) \, ds\right]
$$

One of the popular mathematical models used for analyzing waiting time data is the Cox proportional hazards model (see Andersen (1991), Cox (1972)). In the context of this model, the risk function at time t for pedestrian i can be written as,

$$
\xi(t, R_i) = \bar{\xi}(t) f(R_i, \chi)
$$

where $\bar{\xi}(t)$ is referred to as the underlying risk or hazard, $f(., .)$ is some non-negative function, and $\chi$ is a row vector of unknown parameters. In the context of pedestrians crossing streets, the $R_i$ is time-independent. This issue will be discussed later. Allowing $\bar{\xi}(t)$ being quite general has the advantage of providing reasonably good relative efficiency for the estimation of $R$ without
having to make assumptions about $\xi(t)$. To model the association between vector of predictors $\mathbf{R}$ and the waiting time $t$, the Cox proportional hazards model can be written as,

$$
\xi(t|R) \sim \exp\left( \sum_{i=1}^{N} \xi_{i} \mathbf{R}_{i} + \mathbf{R} \right) \quad \text{with} \quad 0 \leq \xi(t|R) < \infty
$$

where $\mathbf{R}=\{ \mathbf{R}_{1}, \mathbf{R}_{2}, \mathbf{R}_{3}, \ldots, \mathbf{R}_{N} \}$. Clearly, the above model gives an expression for the risk at time $t$ for a pedestrian with a given specification of a set of predictors ($\mathbf{R}$). That is, the vector $\mathbf{R}$ represents a collection of variables that is being modeled to predict a pedestrian’s risk. The exponential expression describes the risk of failure for pedestrian with regression variable $\mathbf{R}$ relative to that at a standard value $\mathbf{R} = 0$ (at all time points).

Maximizing the likelihood function derives the maximum likelihood estimates of the model’s parameters. The partial log-likelihood ($\ln L$) is defined as the sum of the pedestrian likelihoods. Let $C_i$ represents pedestrians ending their waiting time at the same time $t_i$. To account for ties in the data, the partial log-likelihood function can be written as,

$$
\ln L = \sum_{i=1}^{N} \left[ \Psi\sum_{j \in T_i}^{R_j} - C_i \ln \sum_{j \in k_i} e^{\Psi R_i} \right]
$$

where $k_i$ represents the index set of pedestrians with crossing duration greater than or equal to $t_i$. As such, for every pedestrian $j$ in the set $k_i$, $t_j \geq T_i$, where the $T$’s are the pedestrian times to cross the street. The partial log-likelihood is maximized using Newton’s iterative method.

### 3.2 Number of crossing attempts

Pedestrians at the pedestrian crossing usually make a number of attempts before successfully crossing the street. They carry out these attempts because drivers on average do not give way to pedestrians. Pedestrians will remain on the sidewalk (except for risk takers), wait, and make further attempts to cross the street. It is assumed that the number of attempts, a random variable, is influenced by a complex interaction of variables. The objective is to model the number of attempts it takes a pedestrian to successfully cross the street.

In accounting for the randomness of traffic disruption, the obvious choice for the distribution of the number of attempts ($P$) is the Poisson distribution with parameter $\delta$. Observed number of trials made by pedestrians show that the mean and the variance are not the same but
they do not widely differ. As such, both the Poisson and the negative binomial models will be estimated.

The Poisson probability \( P_r(P_i) \) of pedestrian \( i \) making \( P \) attempts to cross the street can be given as,

\[
P_r(P_i) = \exp(-\delta_i)\delta_i^P/(P_i!)
\]

Where \( \delta_i \) is the Poisson model parameter for pedestrian \( i \) which will be a function of measured external factors (vector \( \mathbf{R} \)). Formally, this parameter can be written as,

\[
\ln(\delta_i) = \tau\mathbf{R}_i
\]

where \( \tau \) is a vector of estimable parameters. These parameters are estimated from the likelihood function for \( N \) observed pedestrians. Formally, the likelihood and log-likelihood functions can be written respectively as,

\[
L(v) = \prod_{i=1}^{N} \exp[-\exp(v\mathbf{R}_i)]\exp(v\mathbf{R}_i)^{P_i}/(P_i!)
\]

\[
\ln L(v) = \sum_{i=1}^{N} [-\delta_i + P_i(v\mathbf{R}_i) - \ln(P_i)! ]
\]

and the likelihood equations are

\[
\partial\ln L(v)/\partial v = \sum_{i=1}^{N} [P_i - \delta_i] \mathbf{R}_i = 0
\]

4. Empirical Results

Table 1 shows the maximum likelihood estimation results of the pedestrian’s waiting time at pedestrian crossings. The likelihood ratio test clearly demonstrates the overall goodness-of-fit of the estimated waiting time model. The statistical significance of each individual variable
is given by the t-ratio. All included variables are statistically significantly different from zero at the 5 or the 10% level (one-tailed test).

Estimation results show that pedestrians who were involved or witnessed pedestrian accident(s), have a lower risk of ceasing their waiting time at pedestrian crossings. In other words, these pedestrians have higher waiting time. In addition, female pedestrians, pedestrians with children, pedestrians who own and drive private vehicles, and older pedestrians are not likely to accept higher risk and end their waiting time at the curbside. Griffiths et al. (1984) reported that elderly pedestrians were only prepared to step onto the roadway when it was clear that a driver had yielded the right of way or the road was clear of approaching vehicles. Pedestrians who own and drive private vehicles have a greater perception of risk than non-drivers. On the other hand, the waiting time at pedestrian crossings seem to decrease if the pedestrian is destined to work, low vehicle headway, frequently uses the pedestrian crossing, and the number of people in a group attempting to cross is high. These results support the notion that when pedestrians are in a hurry to get to the work place they are more likely to accept higher risk and end their waiting time. Furthermore, pedestrians waiting time is likely to decrease with increased pedestrian flow as more pedestrians are able to take advantage of an established pedestrian precedence. Griffiths et al. (1984) and Himanen and Kulmala (1984) reported similar outcomes. Katz et al. (1995) indicated that drivers give the right of way more often for crossing pedestrians as a group, rather than as individuals.

One advantage of the proportional hazards model is that it can take both indicator and continuous variables. To assess the effect of included variables on the waiting time at pedestrian crossings, the hazard ratios for both indicator and continuous variables are computed. Table 2 shows estimates of hazard ratios and their corresponding 95% confidence intervals for indicator variables for pedestrians crossing undivided streets. Estimates show that pedestrians who had never been involved or witnessed a pedestrian accident are 3.21 times more likely than those who have witnessed or were involved in a pedestrian accident to have shorter waiting times at pedestrian crossings. In addition, pedestrian who have no access to private cars are 2.4 times more likely than those who own and drive private cars to have shorter waiting times at pedestrian crossings. In addition, pedestrian who have no access to private cars are 2.4 times more likely than those who own and drive private cars to have shorter waiting times at pedestrian crossings.

Pedestrians who are destined to work are 1.84 times more likely than those who are destined to other places to have shorter waiting times. Male pedestrians are 2.61 times more likely than female pedestrians to have shorter waiting times. Finally, pedestrians who frequently use pedestrian crossings are 1.34 times more likely to have shorter waiting times at pedestrian crossings.
Table 3 shows the Poisson regression maximum likelihood estimation results for the number of pedestrian’s attempts to successfully cross the street. Both the Poisson and the negative binomial regression models were estimated. Estimation results showed that the negative binomial dispersion parameter is not significant (t-ratio = 0.878). The insignificance of the dispersion parameter clearly rules out the adoption of the negative binomial regression model and gives support to the Poisson regression model.

The pedestrian’s expected waiting time turned out to have a profound impact on the number of attempts required to cross the street. As the pedestrian’s waiting time increases so does the number of attempts required for a successful crossing. This clearly supports the notion that, the longer pedestrians wait the more they attempt to cross the street i.e. eventually they try to be bold in hopes of forcing approaching vehicles to brake as they cross. However, most of the time they are not successful, as such they continue to make more attempts until they have successfully cross the street. Pedestrians who frequently cross pedestrian crossings, come from work and are destined to home, live nearby the pedestrian crossing, single, and are aged between 20 and 30 years make fewer attempts to accomplish a successful crossing. However, pedestrians attempting to accomplish a successful crossing during the morning peak hour (between 7:00 am and 8:00 am) are likely to require a greater amount of attempts. This is expected and reflects the lack of acceptable and safe gaps between vehicles as perceived by pedestrians. The positive sign of approaching traffic volume supports this. Griffiths et al. (1984) reported that pedestrians have difficulty in establishing precedence when traffic is heavy and fast moving.

Results in Table 3 also show that the type of approaching vehicle seem to significantly influence the number of attempts needed to cross the street. Pedestrians are likely to end their waiting and hence number of attempts if the approaching vehicle was a large bus. However, if the approaching vehicle was a passenger vehicle, then the pedestrian is likely to have a greater number of attempts in order to achieve a successful crossing.

5. Summary and Conclusion

This paper introduces a methodology, combining duration and count models to study the behavior of pedestrians at pedestrian crossings located at undivided urban streets. Findings from this paper is partly supplemented those found in previous research that is based on other theoretical derived models, in particular, those with a specifically attitudinal focus.
Proportional hazard models are specified and estimated to identify the determinants of pedestrians waiting time (delay) on pedestrian crossings. In addition, Poisson regression models are specified and estimated to model the number of attempts required for successful crossing. Estimated Poisson regression models clearly indicate the inappropriateness of the negative binomial regression structure to model the frequency with which pedestrians cross the street. The pedestrian’s expected waiting time was included in the number of attempts model.

Estimation results for undivided streets suggest that predictors that are likely to make pedestrians accept higher risk and end their waiting time and other predictors that are likely to lower the risk and end their waiting time at pedestrian crossings. For example, pedestrians who frequently use a certain pedestrian crossing and who live nearby the crossing are likely to accept higher risk and end their waiting time at the pedestrian crossing. On the other hand, the pedestrian’s past involvement in a traffic accident seem to inhibit the pedestrian from accepting higher risk to end their waiting time (i.e. they have higher waiting time than those who had no previous involvement). Furthermore, pedestrians who have access to private vehicles seem to be more aware of the risk involved. Therefore, they are more cautious of time needed before crossing. In addition, results reported in this paper clearly indicated that the pedestrian’s expected waiting time has a profound impact on the number of attempts required by the pedestrian to make a successful crossing. It seems pedestrians are more sensitive to the waiting time than number of attempts.

The results indicate that approaching traffic volume and vehicle speeds are instrumental in determining the pedestrian waiting time (delay) and the number of crossing attempts. Thus, punishment programs directed at drivers by traffic law enforcement are likely to be instrumental in suppressing undesired risky behavior. Measures such as small fines for offending drivers are not likely to be good deterrent for offenses (see Groeger and Rothengatter (1998)). Repeated offenders at pedestrian crossings should be subject to having their driver license revoked. In addition, these drivers should attend specially designed pedestrian-oriented compulsory training courses. Pedestrians should be targeted through educational and public information campaigns to deter pedestrians from engaging in risky behavior and to promote safe road crossing behavior. Such programs could be applied through mass media messages. Groeger and Rothengatter (1998) reported that educational programs for road crossing skills proved very effective. It is hoped that this piece of work will increase the sophistication of measurement in this area to better understand pedestrians’ behavior on pedestrian crossings.
References


Landles, J. R. (1983) The overall effect on accidents at sites where zebra crossings were installed. Traffic Engineering and Control 24, 9-11.


Table 1. Pedestrians’ waiting time at pedestrian crossing on undivided urban streets.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient / t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>If the pedestrian was involved or have wetness an accident (1 if yes, 0 otherwise)</td>
<td>-1.1640 / -2.350</td>
</tr>
<tr>
<td>If the pedestrian owns and drives a car (1 if yes, 0 otherwise)</td>
<td>-0.877 / -2.467</td>
</tr>
<tr>
<td>Number of people in the group attempting to cross</td>
<td>1.858 / 2.133</td>
</tr>
<tr>
<td>Destined to work (1 if yes, 0 otherwise)</td>
<td>0.612 / 1.600</td>
</tr>
<tr>
<td>Vehicle time headway (in seconds)</td>
<td>1.688 / 1.939</td>
</tr>
<tr>
<td>Number of children in household</td>
<td>-0.364 / -1.823</td>
</tr>
<tr>
<td>Gender (1 if female)</td>
<td>-0.959 / -3.071</td>
</tr>
<tr>
<td>Age in years</td>
<td>-0.184 / -2.524</td>
</tr>
<tr>
<td>Crossing frequency (1 if frequently, 0 otherwise)</td>
<td>0.291 / 1.303</td>
</tr>
<tr>
<td>Long - likelihood convergence model</td>
<td>-398.004</td>
</tr>
<tr>
<td>Chi-squared (k=9) model</td>
<td>64.089</td>
</tr>
<tr>
<td>Significance level model</td>
<td>0.0000</td>
</tr>
<tr>
<td>Log - rank test with 9 degrees of:</td>
<td></td>
</tr>
<tr>
<td>- Chi-squared value</td>
<td>49.089</td>
</tr>
<tr>
<td>- Probability</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

Table 2. Estimates of hazard ratios for pedestrians crossing undivided streets

<table>
<thead>
<tr>
<th>Indicator variable</th>
<th>Hazard ratio</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>If pedestrian was involved or witnessed an accident</td>
<td>0.312</td>
<td>0.118 - 0.824</td>
</tr>
<tr>
<td>If a pedestrian owns or drives a car</td>
<td>0.416</td>
<td>0.208 - 0.834</td>
</tr>
<tr>
<td>If a pedestrian is destined to work</td>
<td>1.844</td>
<td>0.871 - 3.907</td>
</tr>
<tr>
<td>Gender (1 if male)</td>
<td>0.383</td>
<td>0.208 - 0.707</td>
</tr>
<tr>
<td>Crossing frequency (1 if frequently)</td>
<td>1.338</td>
<td>0.864 - 2.071</td>
</tr>
</tbody>
</table>

Table 3. Number of crossing attempts on undivided urban streets via Poisson regression

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient / t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-6.716 / -1.368</td>
</tr>
<tr>
<td>Natural Logarithmic of pedestrian waiting time (from Table 1)</td>
<td>0.866 / 2.434</td>
</tr>
<tr>
<td>Crossing frequency (1 if frequently, 0 otherwise)</td>
<td>-1.001 / -2.039</td>
</tr>
<tr>
<td>Approaching traffic volume (veh/min)</td>
<td>-0.003 / -1.531</td>
</tr>
<tr>
<td>Approaching vehicle speed (1 if between 40 and 60 Km/h, 0 otherwise)</td>
<td>-0.391 / -1.651</td>
</tr>
<tr>
<td>Origin (1 if coming from work and destined to home)</td>
<td>-0.552 / -1.774</td>
</tr>
<tr>
<td>Living nearby (1 if yes, 0 otherwise)</td>
<td>-0.327 / -1.596</td>
</tr>
<tr>
<td>Time of day (1 if between 7:00 am and 8:00 a, 0 otherwise)</td>
<td>0.305 / 2.221</td>
</tr>
<tr>
<td>Martial status (1 if single, 0 otherwise )</td>
<td>-0.095 / -2.145</td>
</tr>
<tr>
<td>Age (1 if between 20 and 30 years, 0 otherwise)</td>
<td>-0.554 / -2.200</td>
</tr>
<tr>
<td>Type of approaching vehicle (1 if large bus, 0 otherwise)</td>
<td>-0.090 / -2.460</td>
</tr>
<tr>
<td>Type of approaching vehicle (1 if passenger car, 0 otherwise)</td>
<td>0.153 / 1.713</td>
</tr>
<tr>
<td>Log - likelihood at convergence =</td>
<td>-142.385</td>
</tr>
<tr>
<td>Chi-squared (k=11) =</td>
<td>84.550</td>
</tr>
<tr>
<td>significance level =</td>
<td>0.0000</td>
</tr>
</tbody>
</table>
Session 7. ALCOHOL, DRUGS AND ENFORCEMENT

Alcohol, illegal drugs and driving in Belgium
Ward Vanlaar, Belgian Road Safety Institute, Belgium

Automatic speed control – The Danish pilot project
Lárus Ágústsson, Danish Road Directorate, Denmark

Reduction of BAC limit from 0.05 to 0.02 percent in Norway – effects on driver knowledge and behavior - some preliminary results
Terje Assum, TÖI, Norway
ALCOHOL, ILLEGAL DRUGS AND DRIVING IN BELGIUM
Using a Decision Tree as a Tool for an Efficient Police Enforcement Strategy

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Abstract

In this article we want to indicate how police officers should divide their time between two legal instruments: on the one hand, the law that prohibits drink driving (law of 18 July 1990) and, on the other hand, the new law prohibiting driving under the influence of certain well-defined illegal drugs (law of 16 March 1999). We base this time allocation on the assumption that police forces have limited resources. If drink driving exerts a different influence on road safety than driving under the influence of illegal drugs, then a well-founded complementary system must be developed for implementing the two laws. For this reason, we have created a theoretical framework as the core of a decision tree. The framework is based on a literature survey of three major concepts regarding drink driving and driving under the influence of illegal drugs (extent of the two phenomena, accident risk and accident consequences) and a thorough evaluation of the two laws in question. The decision tree is a tool that helps to translate theoretical implications into a real-world, efficient police enforcement strategy. In short, our decision tree favours a differential approach to drink driving and driving under the influence of illegal drugs, as the literature survey reveals that there are significant differences between the problem of drink driving and the problem of driving under the influence of illegal drugs.

Keywords: efficient police enforcement strategy, decision tree, drink driving, driving under the influence of illegal drugs

Introduction1

Over the last ten years, the law of 16 March 1968 on the policing of road traffic, the so-called road-traffic law, has been radically modified in order to achieve better police and judicial methods for tackling drink driving and driving under the influence of illegal drugs.

With the law of 18 July 1990 amending the law on policing road traffic, which came into force on 1 December 1994, the legislation regarding drink driving and its detection was radically modified. The most important innovations that the law of 18 July 1990 introduced were that the blood test was in most cases replaced by electronic analysis of exhaled air; the current breath test was replaced by a test using a new device; the punishable alcohol level was lowered to 0.5 gram per litre of blood or 0.22 milligram per litre of exhaled alveolar air; and the penalty for driving under the influence (from 0.8 gram per litre of blood, or 0.35 milligram per litre of exhaled alveolar air) was raised.

In 1999 the law on the policing of road traffic was radically revised once again, this time by the law of 16 March 1999, which came into force on 9 April 1999. This amendment concentrated on the problem of adequately tackling drivers or operators of vehicles or riding animals, under the influence of specific illegal substances in a public place. These illegal substances are cocaine, opiates, amphetamines and designer amphetamines, and cannabis derivatives. The most significant innovation of this law is that it remedies the status of immunity from prosecution of drivers or operators of vehicles or riding animals who are using illegal drugs, but still seem to have control over their actions (Glorieux, 1999). Before the new law came into force, the driver/operator was only punishable if he

1 This article is strongly based on the article by Vanlaar & Goossens (2000).
was in a “state equivalent” to drunkenness. The Court of Cassation clarified this as “the condition where a person has lost permanent control over his actions, without having lost consciousness”. Henceforth, as a driver or operator of a vehicle or riding animal, you are also punishable if you have at least one of the illegal drugs specified in the new law in your body, and the amount present exceeds a legally specified limit. The law provides a three-stage detection system for checking for the presence of such substances and their quantities. First, a standardised battery of tests is used to look for outward signs of intoxication on the suspect’s driving skills by one of the substances. This battery of tests still has to be regulated. If the tests confirm the outward signs, a urine sample is taken as a second stage. This sample is subjected to a qualitative immunoassay to detect the presence in the body of at least one of the substances listed in the law. If this urine analysis proves positive, then a third stage involves the suspect’s undergoing a blood test. It is the blood test that will determine whether the punishable level of the substance in question has been reached. To have legally valid evidence on the matter, all three stages must be gone through.

In this article we want to indicate how police officers2 should divide their time between two legal instruments: on the one hand, the law that prohibits drink driving (law of 18 July 1990) and, on the other hand, the law prohibiting driving under the influence of illegal drugs (law of 16 March 1999). We based this time allocation on the assumption that police forces have limited resources. For example, empirical research revealed that the number of roadside tests in Belgium is much too low to reduce the problem of drink driving (Vanlaar, 1999). If drink driving exerts a different influence on road safety than driving under the influence of illegal drugs, then a well-founded complementary system must be developed for implementing the two laws. For this reason, we have created a theoretical framework as the core of a decision tree. The framework is based on a literature survey of three majors concepts regarding drink driving and driving under the influence of illegal drugs (extent of the two phenomena, accident risk and accident consequences), and on a thorough evaluation of the two laws in question. The decision tree is a tool that helps to translate theoretical implications into a real-world, efficient police enforcement strategy.

The Effect of Alcohol and Illegal Drugs on Road safety3

The Extent of Driving under the Influence of Alcohol and Illegal Drugs

Vanlaar (2000) used a roadside survey to calculate a 95% confidence interval for the extent of drink driving in Belgium. During September, October and November 1998, drivers were subjected to random tests on Saturday nights between 10.00 p.m. and 4.00 a.m. The lower limit of this interval was 8.4%, the upper limit 9.4%. Although such a survey is the best way to determine the extent of drink driving, (Maxim, 1989), we expand the aforementioned results with a number of other indirect measures that can give an indication of the extent of drink driving. Thus, research has shown that there is a positive relationship between per capita consumption and the extent of drink driving (Mann & Anglin, 1990): the greater the per capita consumption, the greater the extent of drink driving. In

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2 The police system in Belgium is currently undergoing fundamental reform. Up to January 2001, Belgium had three police forces: the local police, the state police and the judicial police. In future, these three forces are going to be united into a single integrated police force, structured at 2 levels (federal and local). The federal police was invested on 1 January 2001. Over the course of 2001, the local corps will be established, so that the local police system will be in place by 1 January 2002. At federal level, there is to be a traffic police, with jurisdiction over the motorways. At local level, there is no explicit definition of the remits in relation to traffic.

3 In describing the effect of alcohol and illegal drugs on road safety, we make the abstraction of subjective feelings of lack of safety, this is the worry and anxiety about road safety.
Belgium, the per capita consumption in 1997 was 8.9 litre pure alcohol. This figure indicates an
general decline compared with 1985. In 1997, Belgium took thirteenth place in the world ranking of
alcohol consumption (De Donder, 1999).

As far as Belgium is concerned, there are as yet no representative results for the extent of driving
under the influence of illegal drugs. The data are mainly the result of non-representative police checks.
Although we applaud such actions in the context of police supervision, we still place some question
marks on its value as an objective measurement tool.

The Accident Risk associated with Driving under the Influence of Alcohol and Illegal
Drugs

Borkenstein was a pioneer with regard to calculating the accident risk when one of the drivers is under
the influence of alcohol. In 1964, he wrote the “Grand rapids study” (Borkenstein & Crowther, 1964),
which is still much cited in the literature. He found that drivers with a blood alcohol level of 0.1 pro
mille to 0.4 pro mille have no greater likelihood of being involved in an accident than sober drivers.
Above 0.5 pro mille, the likelihood increases substantially: for example, when the alcohol level is
between 1.4 pro mille and 1.6 pro mille, the likelihood of an accident is 25 times greater. The “Grand
Rapids study” was refined in later research. H.P. Krüger (1995a) investigated the relationship between
the risk of causing an accident and the blood alcohol level.

Although the literature on the accident risk associated with drink driving is quite extensive, literature
on risk data associated with driving under the influence of illegal drugs is much thinner on the ground.
Because of this, the knowledge we have on the effect of illegal drugs on the risk of an accident is not
yet unequivocal (European Transport Safety Council, 1999)\textsuperscript{4}. Haworth and Vulcan (1997) did
investigate the risk of a single vehicle accident of driving under the influence of alcohol and cannabis,
but were not in a position to be able to estimate the effect of cannabis separately. However, they did
find that drivers under the influence of cannabis were usually under the influence of alcohol as well.
Notwithstanding the scarcity of scientific findings, some significant data are available on the
relationship between the use of illegal drugs and road safety. Krüger et al. (1995b) studied 69
epidemiological investigations on alcohol and drugs and driving. They found that the average
percentages of positives for alcohol and illegal drugs were 7 and 15 times higher, respectively, in a
group of injured drivers than in a random sample of drivers. In 1981 Terhune et al. (1981) investigated
the role of alcohol, marihuana and other drugs in accidents where drivers are injured. These analyses
revealed that it is principally alcohol and marihuana that pose a threat to road safety. Other drugs, such
as cocaine and narcotics, were found to a much lesser degree in this group of drivers.

The Severity of Injuries in Road Accidents resulting from Drink Driving and Driving
Under the Influence of Illegal Drugs

Experimental research with animals into the effect of alcohol on the severity of the injuries incurred in
a road accident showed that there is a positive, causal relationship between the degree of alcohol
intoxication and the severity of the trauma. The results have been confirmed for both acute and
chronic intoxication (Anderson, 1986; Benveniste & Thut, 1981; Brodner et al. 1981; Flamm et al.

\textsuperscript{4} Investigators usually have great problems in examining an equivalent accident-free control group. The illegal
nature of illicit drugs and technical problems around screening for the use of illegal drugs, all come into play
(Longo et al., 1996).
metabolic and organic dysfunction resulting from acute and chronic alcohol use increase morbidity and mortality in victims. Warren et al. (1981) examined the role of alcohol in road accidents in Canada on the basis of two investigation groups\textsuperscript{5}. The research results confirmed the theory that had been constructed from experiments: the more alcohol in the blood, the more severe the injuries. House et al. (1982) reported that higher blood alcohol levels are associated with a greater likelihood of serious injury or death. Following on from this finding, Waller et al. (1985) published an investigation in which more than one million accidents were studied in detail. They found that drivers under the influence of alcohol have a greater likelihood of suffering severe injuries or death. In 1997, Waller et al. (1997) - partly on the basis of the above - came to the general conclusion that drink driving unambiguously leads to more severe injuries.

As far as the effect of illegal drugs on the severity of injuries in a road accident is concerned, we are disappointingly short on data: we could find no reports of any experiments to investigate such a relationship. In a fairly recent publication, Waller et al. (1997) made no mention of any laboratory research into the matter. What has been investigated is the question of whether there are any differences in the severity of injuries incurred in a road accident when the influence was due to either alcohol or drug use. Stoduto et al. (1991) said their research showed the answer to this question to be negative. However, contrary to Stoduto et al., Waller et al. (1997) did find a difference. From their research, they came to the conclusion that drink driving is associated with more severe injuries but that this is not the case for driving under the influence of illegal drugs (marihuana, opiates and cocaine): the research of Waller et al. revealed that road-accident victims who were under the influence of illegal drugs fell into the same category of accidents as sober drivers. Data on Belgium is available in the Belgian Toxicology and Trauma Study (Belgian Society of Emergency and Disaster Medicine (BESEDIM), Toxicological Society of Belgium and Luxembourg (BLT), Belgian Road Safety Institute (IBSR), s.d.), carried out in 1995-1996. This study confirmed that alcohol and drug intoxication are associated with greater morbidity and mortality.

**Conclusion**

The scientific investigations cited show us that both alcohol and illegal drugs potentially have an extensive influence on objective road safety. In Belgium - but not only here - however, there is a great lack of information, preventing relevant detailed questions being answered on the relationship between the use of such substances and road safety. This is particularly so with regard to illegal drugs. It would therefore not cut any ice for us to conclude that the impact of illegal drugs on road safety is any greater or less than that of alcohol, on the basis of the partial information that is available. However, what may be concluded is that the legislature is justified in enacting the law of 16 March 1999, given the undeniably adverse influence of the use of illegal drugs on objective road safety. With this, additionally, the legislature links in with the findings of the Sartre survey (De Oliveira & Quimby, 1998) of a thousand drivers per country in the European Union: 58% of the Europeans questioned considered that illegal drugs cause accidents, 61% of the Belgians surveyed were of that opinion. Legal regulations on the detection and establishment of the use of illegal drugs when driving was also necessary from a judicial standpoint. Before the enactment of the law of 16 March 1999, police forces were already carrying out urine tests and blood analyses on their own initiative in districts around large dance halls and on drug-traffic routes, based on the conviction that use of illegal drugs has an

\textsuperscript{5} In comparisons of laboratory experiments and epidemiological research, the results were usually conflicting (see for example: Soderstrom et al., 1987). However, Waller (1987) demonstrated that the cause of this discrepancy lay in the methodology peculiar to the epidemiological research.
adverse effect on road safety. Since such tests were carried out without any legal basis, any “evidence” obtained from them was often labelled as unlawful and could not be used in court. The law of 16 March 1999 rectifies this fundamental problem.

Evaluation of the Legal Armamentarium for Detecting and Establishing the Use of Alcohol and Illegal Drugs amongst Drivers

A first general comment is that the legal armamentarium for detecting intoxication from the use of specific illegal drugs amongst drivers has not been hitherto greatly used. One reason for this is that the test battery, the first stage in the detection process, and its application have not yet been fully finalised. The College of Procurators General has still not yet issued any guidelines on how the test battery should be made up and administered, so that vagueness rules due to a lack of regulations. Legislation - in the form of guidelines from the College - is urgently needed. More specifically, a process needs to be drawn up that is uniform throughout Belgium and preferably for the whole of Europe, laying down what elements make up the test battery and how the battery has to be implemented. It must also be mentioned that the urine test has not yet been regulated in detail: here too, legislation needs to provide for a reliable test.

One might also wonder whether it is appropriate for the drug test to be as lengthy as the legislature has made it, namely with a three-stage check that must be gone through fully for any evidence to be able to hold up in court. We think that the legislature could and should find no other way. In the current status of science, only the introduction of the blood test as the final part of the test can provide evidence of drug intoxication with sufficient certainty. Concentrations in the blood have the advantage that they best show the correlation with the effect of drug use. At the same time, the importance of administering a urine sample is manifest, in particular because concentrations in the urine are 10 to 50 times higher than in the blood and because the detection time with urine is longer: between one and three days. When we put all this together and couple it with the criminal evidence principle that any doubt must be in the accused’s favour, the choice of the legislature for a three-stage drug test seems appropriate. This does not lessen the fact that the quest must continue for easier and faster methods to detect driving in a condition of intoxication resulting from the use of specific illegal drugs. The general conclusions of the ROSITA project (RoadSide Testing Assessment) reveal that there is much progress in the development of more efficient screening tests (Verstraete & Puddu, 2000). These developments are moving very fast, but if the industry were to have greater certainty on the existence of a sufficiently large market for their product, its interest would be more sharply aroused. In Belgium, such a guarantee comes in the form of the new law on driving under the influence of illegal drugs. A clear recommendation is that, despite the ever-better validity of on-site-tests, criminal evidence must continue to be based on analysis in an accredited laboratory. One pleads therefore for maintaining the differentiation between initial screening and more rigorous procedures for collecting criminal evidence. Furthermore, there should also be good training for police officers in recognising symptoms suggestive of the use of illegal drugs, as the use of on-site tests will then be more efficient and economical. Scheers & Van Haeren (2000) also plead for this and make a general proposal on how to provide such training. As far as the use of urine samples is concerned, it has been noted that, given the necessary provisions on the ground, this is an easy way to collect a sample. If there are no toilet facilities available, however, it is not an efficient way to operate. However, tests based on saliva samples and sweat samples are not yet sufficiently well developed to replace tests based on a urine sample.
We find that screening for driving under the influence of illegal drugs takes longer than screening for drink driving. This is partly due to the fact that, for example, administering the test battery takes far more time that doing a breath test. Whereas doing a breath test to find out whether or not alcohol has been consumed allows a selection to be made quite quickly on the basis of an objective measuring device, going through a test battery consisting of some 25 points requires particular attention on the part of the police officer who has to carry out the selection on whether or not illegal drugs may have been used. In addition, detection of illegal drugs in driving requires an extra step, namely the urine test. Administering a urine sample takes a long time in itself. If one then takes into consideration that in administering this test the necessary care with regard to discretion and hygiene has to be taken to protect the suspect’s privacy, it will be evident that administering the urine test will take a long time, particularly if the requisite toilet facilities for taking the urine sample are not available onsite. A final point that makes the drug test time-consuming is connected with the evidence regime regarding intoxication from the use of illegal drugs when driving: it is only by means of a blood test that this condition and this violation can be proven. The blood test is more fundamental and lengthy than the breath analysis that is usually enough to prove drink driving. With the new, portable Dräger machines (model alcotest 7110 be, type MK III) under normal circumstances it usually takes only 5 to 6 minutes to do a complete breath analysis, while for a blood test a doctor must be brought in who then has to take the blood sample according to legal procedures and have it assayed in a laboratory.

In other words, the drug test requires a great deal of time and effort on the part of the police, who meanwhile still in theory have to check for alcohol abuse in road users, using other, less time-consuming procedures. An appropriate allocation of resources is urgently required to achieve efficient police supervision on the use of alcohol and illegal drugs on the road.

The Use of a Decision Tree to Support an Efficient Enforcement Strategy

With a view to efficient policy supervision with regard to road safety, it is important that the - scarce - resources that the police have be divided as evenly and appropriately as possible across the points of attention at issue. In this distribution, account must be taken of the social relevance of the various themes, across which the resources can be shared. In this final part, we formulate a proposal on how police resources should be allocated for detecting and preventing drink driving on the one hand and driving under the influence of illegal drugs on the other.

We favour a differentiated approach to tackling driving under the influence of alcohol and illegal drugs. Because we know with fairly high certainty that drink driving is a major problem in Belgium and because we can expect to find drivers under the influence of alcohol everywhere (Vanlaar, 1999), this problem needs to be combated as part of an enforcement strategy according to the principles of non-selective alcohol checks, based on the deterrent theory. Attention should be paid to general knowledge with regard to police supervision and specific knowledge with regard to the local situation. This involves the organisation of intermittent, non-selective alcohol checks, where as many drivers as possible are stopped and every one of them is subjected to a breath test. Because drink drivers can be found everywhere, check sites can be selected purely on the basis of practical feasibility, safety and traffic density. Moreover, these types of checks get a lot of publicity through a communications plan, without their becoming predictable. Research shows that the police in Belgium need to check at least 545,000 drivers non-selectively per year to expect any effect. This number has not yet been achieved.

As far as driving under the influence of illegal drugs is concerned, as long as there is no clearer picture on the extent and effects of the use of illegal drugs on driving, non-selective methods must also be used, but with the proviso that the target group be sought with more focus. The approach has to be
non-selective because we may assume that drivers under the influence of illegal drugs, whose driving skills have indeed been radically affected, may well try to lead the police up the garden path. Just as with drink driving (Pagano & Taylor, 1979; Gundy & Verschuur, 1986) many drivers could slip through the net, which would not help the credibility and efficiency of traffic management. Secondly, the approach has to be more focused, because in our opinion mass checks everywhere, at any time, and without any refinement with regard to target group would not be warranted. There are guidelines on the age (more young people than elderly) and the location (in specific entertainment areas) of the target group that do need to be taken into account in preventing driving under the influence of specific illegal drugs. Given the lengthier procedure and the assumption that driving under the influence of illegal drugs is a less wide-spread phenomenon than drink driving - precisely because it seems to be related to age and location - it would be redundant to organise tackling drugs on an equally large scale as prohibiting and combating drink driving.

Of course, it is defensible to combine police enforcement on driving under the influence of alcohol and illegal drugs. Let it be clear, however, that we are only in favour of this if it involves an action in those neighbourhoods, at those times and with respect to those target group, for whom there is suspicion that they are driving under the influence of illegal drugs. In other words, if an action is organised on driving under the influence of illegal drugs, alcohol intoxication should always be checked at the same time. Since the procedure for checking alcohol use is less cumbersome than that for checking drivers under the influence of illegal drugs, checks for alcohol intoxication take priority. If a driver proves negative on that check, then the test battery mentioned above is carried out anyhow. “Anyhow” because this is the condition to ensure that checks are non-selective. If the driver shows positive in the breath test, then there is little point in continuing with the test battery as far as road safety is concerned: the driver can already have a driving ban imposed because he drove under the influence of alcohol.

However, if an action on drink driving is involved, then it should not automatically be combined with a check on driving under the influence of illegal drugs. Such a link should only be made if checks are being done in those neighbourhoods, at those times and on those target groups, for which there is a suspicion that they may be linked to potential violations of the law of 16 March 1999. In practice, this means therefore that one should be capable on a single check night, depending on the location, of very dynamically changing over from one mixed, dual check to a single check. The initiative of Antwerp Province to provide the police with a special vehicle with toilet facilities is a good example of how this differentiated approach can be put into practice.

Finally, we present our recommendations in a flow chart or decision tree. This provides a comprehensible way of illustrating what we have said above. The decision tree can be an aid in preparing an action on driving under the influence of alcohol and/or illegal drugs. Although we have developed such a decision tree, it is still difficult to indicate how time and resources should be divided for detecting alcohol and illegal drugs in practical terms. Whatever the case, one must bear in mind that tackling neither drink driving nor driving under the influence of drugs can be ignored.
Conclusion

It is certainly justified for a legal armamentarium to have been developed to detect drivers under the influence of illegal drugs. All the more so, from the standpoint that the requirements of adequate criminal proceedings and verification in criminal trials demanded regulations on the matter. However, so that drug tests could be fully developed and therefore enable the police to detect and prevent intoxication due to the use of specific illegal drugs, further legislation is also essential, in particular on the test battery and the urine sample. The executive authority and the college of Procurators General should hasten to fulfil their role.

The complexity of the drug test, consisting of three - often time-consuming - phases, is justified from the point of view of scientific certainty on use of illegal drugs while driving. This complexity, however, means that police resources will have to be distributed efficiently between tackling the use of illegal drugs and driving on the one hand and tackling drink driving on the other. Because it is assumed that the impact of drink driving on objective road safety differs from the impact of driving under the influence of illegal drugs, despite a lack of literature and research on the matter, we favour a differentiated approach to the two problems. In this article, we have endeavoured to make a contribution to such a differentiated approach, which should lead to efficient police supervision, with the available resources distributed evenly between both phenomena.

The problem of allocating police resources may become even sharper in the future, if the legislature were to decide to include driving under the influence of other illegal drugs (for example designer drugs and hallucinogenic drugs as LSD and magic mushrooms) or under intoxication of certain medicines as a punishable offence. At present, people who take medicines and then drive, and who apparently still have control over their actions cannot be prosecuted. Since there are noises suggesting that medicines can lead to risky driving behaviour through either their therapeutic action or their side effects (Scheers & Van Haeren, 2000), it is quite possible that the legislature will amend traffic law

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Differentiated policy on drink driving and driving under the influence of illegal drugs

- **Alcohol**
  - Select sites on the basis of: practical feasibility safety traffic density
  - If drivers suspected of being under the influence of illegal drugs are present:
    - Non-selective alcohol checks
      - Negative
        - 3-hour or 6-hour driving ban
      - Positive
        - Driver may proceed
  - If drivers suspected of being under the influence of illegal drugs are not present:
    - Non-selective alcohol checks
      - Negative
        - 3-hour or 6-hour driving ban
      - Positive
        - Non-selective drugs check
          - Negative
            - 12-hour driving ban
          - Positive
            - Driver may proceed

- **Illegal drugs**
  - Select sites based on suspicions regarding: target group location timing
  - Non-selective drug checks
    - Negative
      - 3-hour or 6-hour driving ban
    - Positive
      - Driver may proceed
accordingly. If that occurs, the issue of how to allocate police resources with regard to maintaining road safety will have to be re-assessed.
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BELGIAN SOCIETY OF EMERGENCY AND DISASTER MEDICINE (BESEDIM), TOXICOLOGICAL SOCIETY OF BELGIUM AND LUXEMBOURG (BLT), BELGISCH INSTITUUT VOOR DE VERKEERSVEILIGHEID (BIVV) (s.d.) Belgian Toxicology and Trauma Study. (s.l.), (s.e.).


Traffic and Accidents in Denmark

In Denmark 5.2 million inhabitants live on 44,000 square km (table 1).

The road network is 70,000 km long and 2 million vehicles drive approximately 44 billion kilometres a year.

As in the majority of the western European countries we have seen a great reduction of accidents in Denmark the past 30 years (figure 1). In 1971 the number of road fatalities was almost three times as high as in 2000. During the same period the traffic grew from 22 to 44 billion vehicle km. A great reduction in the frequency of accidents has taken place – road traffic is now approximately five times safer than it was 25 years ago /1/.

The overall goal of the first Danish Road Safety Action plan from 1989 was to reduce the number of fatalities and casualties by 40% from the average of the period 1986 - 1987 to the year 2000, /2/. The plan did not entirely reach that goal, however a 30% reduction in casualties is considered very satisfying.

The goal of the new Danish Road Safety Action Plan from last year is to reduce the number of fatalities and serious casualties by 40% from 1998 to the year 2012, /3/. This plan is ambitiously entitled "Each
Accident is One too Many”. The idea is that fatalities and casualties should not be accepted neither by the road authorities nor by road users everyday. The Swedish zero vision inspires this idea. The main areas of action are:

- Accidents caused by speeding
- Accidents caused by intoxicated drivers
- Accidents with bicyclists
- Accidents at intersections.

Of course some overlapping between these areas will occur. For each area a number of 62 actions are suggested. One example of suggested actions is the use of enforcement technology like the automatic speed control. Automatic speed control is the term we use in Denmark for a police officer in a car with a camera that automatically takes pictures of speeding cars.

**Speed and Enforcement Technology**

![Graph showing the reduction in killed and injured accidents in relation to the reduction in average speed.](image)

A large amount of traffic accidents are caused by speeding cars. Furthermore, the faster the car is going when an accident occur the more severe the consequences of the accident will be. Research shows that a 10% speed reduction can give an estimated 25% reduction in casualties and at least a 35% reduction in fatalities (figure 3).

This is why one of the most important goals when ensuring road safety is to reduce car speed.

The general speed limit in Danish urban areas was reduced from 60 km/h to 50 km/h in 1985.

The outcome of this reduction was lower average running speed and followed by fewer accidents, although speed measurements in the subsequent years still showed a low universal adjustment to the new limit.

In urban areas the average running speed is around 52 - 55 km/h. The past 10 years the average running speed has been almost unchanged on major rural roads. On rural roads the speed limit is 80 km/h in Denmark. The average running speed is on rural roads is approximately 88 km/h. On motorways, however, the average running speed has increased with about 0,5 km/year [lit. 3]. The speed limit is 110 km/h but the average running speed is around 114 km/h.

Research shows that if the average speed on all roads in Denmark corresponded to the speed limit there would be:
each year! This is why automatic speed control was introduced in Denmark.

Where and When?
The Automatic Speed Control pilot project was originally carried out in two Danish areas. The largest area has been the metropolitan area of Copenhagen. On the island of Funen the city of Odense, Svendborg and some smaller villages have been appointed proving ground (figure 4).

After some small trial projects in 1997 – 1998 the pilot project started at the 6th of April 1999 and ended the 1st of April 2000.

Method
The control equipment is placed in the back of a van. The assigned police officer is able to move the equipment between several sites during the day. A site for traffic control is chosen from a list of roads where many accidents occur. The list is made from accident statistics and compiled in co-operation between the police and the municipality in question and the Road Directorate.

The police officer drives the van to a chosen site on the road network. At the site the radar measures the speed of the cars driving by (figure 4). If a car is speeding, the camera takes pictures of the car showing the licence plate and the face of the driver.
When the police officer gets back to the office, the film is developed, digitised and merged into a computer. New software has been developed to administer this process. With this software clerks at the police office check the quality of the picture and enter the registration number of the car into the computer. The software finds the name and address of the owner of the car and sends a letter to the owner including the picture. In this letter the owner is told to phone or fax to the police to inform who was driving the car at the time of the violation. The Danish Traffic Code says that the car owner is obliged to tell the police the name of the driver on request. If the owner refuses he is penalized with a fine. If the owner does not respond to the letter, the police will contact him by phone or by a visit.

When the police has got the name of the driver, the driver receives a fine corresponding to the driven speed.

### Information and Campaigns

An important component of the project was information and campaigns. At the outset of the project, the municipalities put up signs in the proving grounds reminding the drivers of the control. Leaflets were made and sent out to libraries, petrol stations, police stations and municipality offices (figure 6). An Internet homepage was made: [www.fartkontrol.dk](http://www.fartkontrol.dk) (in Danish only). The campaigns also included advertising in newspapers as well as television spots. The Road Directorate was in charge of the information on the project.

### Budget

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<tr>
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<td>The Police</td>
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<td>- Information</td>
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Table 1 shows the overall budget of the project. The budget of the pilot project was 45 million DKK, which amounts to approximately 5.3 million US dollars. The Police and the Road Directorate shared the expenses. The Police was in charge of the equipment, the control and administration. The Road Directorate was in charge of evaluation, project management and information. The budget includes police wages and project management.

During period the project was running there were 105,000 cases of speeding. This number corresponds to the amount of cases involving speed in the entire country before the project started. On average a fine was 585 DKK or 69 USDollars which meant an income of about 60 million DKK or 7.06 million US dollars from fines. Further more the project resulted in saving lives and reducing the amount of casualties, car damages, road furniture damages and environmental savings (noise, pollution,
from fines. Further more the project resulted in saving lives and reducing the amount of casualties, car damages, road furniture damages and environmental savings (noise, pollution, etc.).

**Results of the Pilot Project**

The evaluation of the project is based on measuring speed at 20 selected sites inside the control areas and 10 sites outside the proving grounds for comparison. The results show a 2.4 km/h reduction in average running speed inside the zones and no changes outside the areas during the last month of the pilot project (figure 7).

The results however differ from area to area. In the Copenhagen area the reduction was about 3 km/h. and in the town of Svendborg the results was a reduction in average running speed of about 2 km/h whereas in Odense the reduction was 1,5 km/h.

![Figure 7. Average Speed, /4/](image)

The equipment was in operation in average around 2 hours a day. In the 12 month period of the pilot project 105.000 fines with pictures were sent out (figure 8), all though 155.000 pictures were taken. All in all 50.000 pictures were thrown out because the quality was not satisfactory – usually because the driver or the license plate was not entirely visible. Around 3200 cases were taken to court. The police lost only 3 of those.

![Figure 8. Administration, /4/](image)

The Road Directorate finished the evaluation report in august 2000. Accident statistics from the pilot project will be evaluated when sufficient accident data is available.
The Danish Road Safety Board has conducted a survey in which the citizens were asked what they thought of automatic speed control. In 1997 only half of the people asked, said that they approved the control. In 1999, after the pilot project was started, 2/3 approved the control. In 1999 more people had an opinion about the control because the subject had been widely debated in the media that year.

The Future of Automatic Speed Control in Denmark

After examining the results, the Danish Parliament has decided to permanently implement automatic speed control in the entire country. The process of implementing speed enforcement technology began on the 1st of July this year and will continue for the next 2 years.

The speed enforcement will be carried out from 9 regional offices that will be established one by one during the transition period. In 2001 13 of the 54 police districts will carry out the control, covering around 20% of Denmark. More than 50% of the inhabitants live in those areas. All major Danish cities will have speed enforcement technology by March 2002.

Each of the regional offices will have 3-4 sets of equipment for controlling the speed in an area of on average 10,000 km² with a total of on average 7,500-km of roads and streets.

As in the pilot project, the police will primarily control roads and streets where many accidents occur. But also streets near schools and other institutions, roads with roadwork and major roads through small villages will be controlled as the permanent system of automatic traffic control take effect. The local authorities and the Road Directorate will prioritise the road network in co-operation with the police. However, the police are entitled to control any road on the road network they feel pose a threat to traffic safety. The roads that are chosen by the Road Directorate and the local authorities are only to be considered as a guideline for the police. A successful introduction of speed enforcement technology using the Danish method depends very much on the ability of the authorities to co-operate.

A major difference between the pilot project and the permanent implementation of automatic speed control is the question of whether or not to put up signs. During the pilot project signs were put up in the test areas to warn drivers of the automatic speed control. However, the idea of introducing the technology in the entire country is principally to ensure every single road in Denmark. Therefore no signs will warn drivers of the control in the future. By taking this step
the message to the Danish drivers is that if you are speeding you risk getting caught on camera everywhere in the country. This is naturally a controversial issue and has been the subject of many public debates. In order to follow up on the debates a new campaign has been launched.

The campaign strategy is to draw attention to the improvement in traffic safety the use of enforcement technology is expected to have. The logo for the campaign is a camera with a flash on blue background (See figure 9). It is important that the logo is easy to remember due to its potential preventive effect – especially when posters are put up on the back of busses or alongside the road carrying the logo. If the drivers are aware that the speed limits will be enforced they will drive more carefully. And after all that is what this is all about.

The First Results of the New Project

During the first couple of months the permanent implementation of automatic traffic control has been very successful in the areas in question. In one of the new areas the average running speed was reduced with about 2 km/h during the first month. That is to be considered a sizeable reduction especially when you take into account that it was during the holiday season.

Literature

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REDUCTION OF BAC LIMIT FROM 0.05 TO 0.02 PERCENT IN NORWAY – EFFECTS ON DRIVER KNOWLEDGE AND BEHAVIOR

SOME PRELIMINARY RESULTS

By Terje Assum, Senior Research Officer
TØI – Institute of Transport Economics, Oslo, Norway

1 Background

1.1 Drinking and driving increases accident risk

It is a well-established fact that the consumption of alcohol before driving a motor vehicle increases the accident risk (Desapriya & Nobutada, 2000; Glad & Vaas, 1993). However, the importance of rather low blood alcohol concentrations (BAC) for accident risk is still discussed. Norwegian studies (Gjerde et al 1993; Statistics Norway 1992) find that drivers involved in fatal, alcohol-related road accidents have on the average rather high BACs, above 0.1 per cent, whereas Moskowitz & Robinson (1987; p. 84) claim that as to divided attention “Impairment began below .02 %, with 60 percent of the studies reporting impairment at or below .05%.” and further (p.86) “Impairment occurs in most areas at the lowest BAC that can be reliably chemically determined.”

The question is thus what effect a reduction of the legal BAC limit from 0.05 percent to 0.02 per cent will have?

1.2 The legislative amendment: Reduction of BAC limit from 0.05 to 0.02 per cent

As the first country in the world Norway introduced a legal BAC limit of 0.05 percent in 1936, and has a long tradition of strict enforcement, with three weeks imprisonment as the normal punishment up to 1988. After 1988 fines were the normal punishment for first offense up to BAC of 0.15 per cent and imprisonment above BAC of 0.15 percent. In addition the driver’s license was suspended, normally for two years. The attitudes towards drinking and driving, even towards driving with a BAC below the legal limit have been rather reprehensible (Vaas & Elvik, 1992, pp. 29-30).

After Sweden reduced the legal limit from 0.05 to 0.02 per cent in 1990, the pressure for a similar reduction in Norway increased, and the amendment came into effect by January 1, 2001. The stated reasons for this amendment were to reduce the amount of impaired driving and to demonstrate that the driving of a motor vehicle and consumption of alcohol do not belong together. The reduction of alcohol related road accidents were hardly mentioned in the official documents in this matter, but this reduction was maybe taken for granted, if only a reduction in drinking and driving could be achieved.

The normal punishment for driving with a BAC between 0.02 and 0.05 per cent is a fine, and the license is not suspended.

1.3 Hypotheses

Strictly speaking, the reduction of the legal limit should be expected to take effect on driving with BACs in the range of 0.02 to 0.05 percent. However, there is reason to believe that even driving with BAC above 0.05 may be affected according to Mann et al (2001, p. 579): “Most studies that have examined the impact of a lowered legal limit on measures of driver BACs, or BAC levels in arrested or fatally injured drivers, have observed a substantial impact on BAC levels other than those specifically affected by the change in limits.” Two hypotheses are consequently addressed:
The reduction of the legal BAC limit from 0.05 to 0.02 percent will
1. Reduce driving with BAC between 0.02 and 0.05 per cent,
2. Reduce driving with BAC above 0.05 per cent.

2 Method

2.1 Survey of license holders – no control group

As the reduction of alcohol-related road accidents should be the most important objective of
the amendment, the effect should preferably be assessed in terms of possible changes in such
accidents. However, Statistics Norway, which is responsible for the road accident statistics in
Norway, discontinued the production of statistics of alcohol-related accidents in 1996, having
no plans to revive these statistics. Consequently, the only option is assess the effect in terms
of the amount of drinking and driving, taking for granted that a reduction in drinking and
driving will bring about a reduction in alcohol-related accidents. Drinking and driving is most
reliably measured by roadside surveys. Such surveys are however, rather costly, and therefore
the Norwegian authorities did not want a roadside survey. A survey of driver knowledge and
behavior was then made by questionnaire to a random sample of Norwegian license holders
before and after the amendment, June 1998 and June 2001, respectively.

The legal amendment was made effective for the whole country at the same time. Establishing
a control group of drivers not affected by the amendment was consequently not possible. In
principle it is therefore not possible to state whether changes in driver knowledge and
behavior observed between 1998 and 2001 are due to the legal amendment or to other factors.

2.2 Operationalization

2.2.1 Drinking and driving

Drinking and driving was measured by the following questions:

* How much alcohol would you drink before driving an hour later?
* How likely are you to drive with a BAC above the legal limit within the next three years?
* How likely are you to drive after drinking, but with a BAC below the legal limit within the
next three years?

In addition the following question was asked in 2001:

* How likely are you to drive with a BAC above the former legal limit of 0.05 percent within the
next three years?

2.2.2 Other questions

In addition questions were asked about knowledge, perceived risk and behavior such as:

- Knowledge of legal limit
- Knowledge of amount of alcohol required reaching the limit
- Perceived risk of apprehension
- Knowledge about penalties for drinking and driving
- Social norms of drinking and driving
- The use of a car when going to occasions where alcohol is expected to be served
- Frequency of designating a driver when going to occasions where alcohol is expected
- Kms driven per year
- Age, gender, education and place of residence

2.3 Data collection

Random samples of driver’s license holders were interviewed by telephone by a professional opinion poll company in June 1998 and June 2001. The response rate was 56 per cent in 1998 and 53 per cent in 2001. A total of 3001 interviews were completed both years.

3 Results

3.1 Knowledge of the BAC limit and the penalty

*Table 1  "According to Norwegian law driving with a blood alcohol concentration above a certain limit is prohibited. Do you know what this limit is?" 1998 and 2001. Percent.*

<table>
<thead>
<tr>
<th>BAC limit, per cent</th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 – 0.01</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>0.02</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>0.03 – 0.04</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>0.05</td>
<td>86</td>
<td>3</td>
</tr>
<tr>
<td>0.06 – 0.08</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Other answers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Not sure</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

To comply with the reduced BAC limit, the drivers have to know the limit. Table 1 shows that 86 per cent of the license holders answered correctly as to the BAC limit both before and after the change. To comply with the rule, it is also necessary to know approximately how much alcohol it takes to get to the limit. Table 2 shows that 47 per cent knew the right answer\(^1\) after the change and 42 percent knew the right answer before.

\(^1\) It is difficult to state the accurate amount of alcohol it takes to get to the limit, but a simplified answer would be two bottles of normal beer (4.5 percent alcohol) to get to a BAC of 0.05 and one bottle of normal beer to get to 0.02 per cent for a man of 70 kg.
Table 2 "How much do you think a man of 70 kg will have to drink within an hour to obtain a BAC a little above the limit (0.05 in 1998; 0.02 in 2001)?" Percent.

<table>
<thead>
<tr>
<th>Amount of alcohol needed to reach the legal limit</th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than a small bottle (0.33 l) of light beer (max 2.5 percent alcohol) or equivalent</td>
<td>*</td>
<td>4</td>
</tr>
<tr>
<td>One small bottle of light beer or equivalent</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>One small bottle of normal beer (4.5 percent alcohol), one glass of wine or equivalent</td>
<td>14</td>
<td>47</td>
</tr>
<tr>
<td>Two small bottles of normal beer or equivalent</td>
<td>42</td>
<td>17</td>
</tr>
<tr>
<td>Three small bottles of beer or equivalent</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Four small bottles of beer or equivalent</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>More than four small bottles of beer or equivalent</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Not sure</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

* Not used as an alternative in 1998

Table 3 "In what way do you think the authorities would react towards a driver having a BAC of 0.03 and a BAC of 0.07" 1998 and 2001. Percent

<table>
<thead>
<tr>
<th>Authorities' reaction to drinking and driving with a BAC of 0.03 and 0.07 percent.</th>
<th>BAC 0.03</th>
<th></th>
<th>BAC 0.07</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No reaction</td>
<td>52</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Warning</td>
<td>28</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fixed fine</td>
<td>4</td>
<td>43</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>Fine dependent upon income</td>
<td>1</td>
<td>21</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td>Suspended imprisonment</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Unqualified imprisonment</td>
<td>0</td>
<td>5</td>
<td>25</td>
<td>34</td>
</tr>
<tr>
<td>Suspension of license for 6 months or less</td>
<td>5</td>
<td>17</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Suspension of license for 6 to 18 months</td>
<td>0</td>
<td>5</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Suspension of license for 18 to 30 months</td>
<td>0</td>
<td>5</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Suspension of license for more than 30 months</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Not sure</td>
<td>13</td>
<td>13</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
<td>121</td>
<td>152</td>
<td>171</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

Knowledge about the penalty for drinking and driving would also be necessary in considering whether or not to drink and drive. The penalty for drinking and driving in Norway is a combination of imprisonment, fines and suspension of the license, depending on the actual BAC level.
Table 3 clearly shows that the majority of Norwegian drivers have realized that the BAC limit is changed. In 1998 80 per cent of the drivers said there would be no reaction or a warning for driving with a BAC of 0.03 percent. In 2001 64 percent said it would be a fine, either fixed or depending upon income, which is the right answer. 8 percent thought that the penalty would be some kind of imprisonment, and 26 percent thought that the license would be suspended, which is not the case. As to the penalty for driving with a BAC of 0.07 percent the answers are pretty much the same before and after the reduction of the limit, except that 20 per more give more than one answer in 2001.

3.2 Subjective risk of apprehension

The risk of apprehension is normally considered one of the more important factors affecting road traffic behavior, i.e. the subjective risk rather than the objective risk. Apprehension statistics are not widely publicized in Norway.

Table 4 shows very small differences in subjective risk of apprehension between 1998 and 2001.

*Table 4* "If during a normal day 1000 people drink and drive, how many do you think would be apprehended?" 1998 and 2001. Percent

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 person</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>2 – 5 persons</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>6-10 persons</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>11-30 persons</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>31-100 persons</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>More than 100 persons</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Not sure</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

3.3 Social norms

People are known to be affected by the social norms. Ajzen and Fishbein (1980; p. 57) describes as “a person’s subjective norm, i.e. his perception that most people who are important to him think he should or should not perform the behavior in question.” Table 5 shows that the subjective norm as to driving after drinking one bottle of beer have changed somewhat, whereas the norm for driving after four bottles of beer has remained the same or become less strict. However, the most striking facts appearing from table 5 is the widespread strictness of the norms against drinking and driving. Even in 1998 63 percent of the drivers claimed that people they knew would dislike their drinking and driving after one bottle of beer even though the majority thought that two bottles or more would be necessary to reach the legal limit of 0.05 percent.
Table 5 "How do you think people you know would react if you drive a car one hour after having had a small bottle of beer or equivalent or four bottles of beer? Would they dislike it a lot, somewhat or wouldn’t they react much or not at all?" 1998 and 2001. Percent.

<table>
<thead>
<tr>
<th>Reaction of people you know</th>
<th>One bottle of beer</th>
<th>Four bottles of beer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dislike a lot</td>
<td>34</td>
<td>41</td>
</tr>
<tr>
<td>Dislike somewhat</td>
<td>29</td>
<td>30</td>
</tr>
<tr>
<td>Wouldn’t react much</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>Wouldn’t react at all</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Not sure</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>2578</td>
<td>2548</td>
</tr>
</tbody>
</table>

3.4 More or less drinking and driving?

A bottle of normal beer (0.33 liter, 4.5 per cent alcohol) would be the maximum amount a man of 70 kilograms could drink and still be on the legal side of the limit. Table 6 shows that only 1 percent in 1998 and 0 percent in 2001 claim that they would drink more than this amount before driving. However, the percentage that would not drink at all before driving has increased from 82 percent to 91 percent.


<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teetotaler (question not asked)</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Nothing when I’m going to drive</td>
<td>68</td>
<td>76</td>
</tr>
<tr>
<td>A small bottle (0.33 liter) of light beer or equivalent</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>A small bottle (0.33 liter) of normal beer or equivalent</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Two small bottles of normal beer or equivalent or more</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

Table 7 shows that two percent in 1998 and 8 percent in 2001 claim they are likely to drive with a BAC above the limit, which may be reasonable, as the limit has been reduced. What is more important is however, the percentage likely to drive with a BAC in the range of 0.02 to 0.05 per cent. This percentage cannot be calculated exactly as questions were only asked above and below 0.05 in 1998. However, the number of license holders likely to drive with a BAC below, but not above 0.05 was 407 or 13.6 percent in 1998 and 398 or 13.3 per cent in 2001, i.e. no change from 1998 to 2001.
Table 7 "How likely are you to drive above the legal limit, below the legal limit and above the former legal limit within the three next years?" 1998 and 2001. Percent

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 0.05</td>
<td>Above 0.05</td>
</tr>
<tr>
<td>Most, quite or a little likely</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>A little or quite unlikely</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Most unlikely</td>
<td>57</td>
<td>77</td>
</tr>
<tr>
<td>Teetotaler (question not asked)</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Not sure</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

Table 7 also shows that the number of drivers likely to drive with a BAC above 0.05 per is more or less the same in 1998 and 2001.

3.5 The use of car to occasions where alcohol is served

As the amount of alcohol that can be consumed without exceeding the BAC limit has been reduced, it is reasonable to expect that people would drive a car to places where alcohol is served to a lesser degree in 2001 than in 1998. However, table 8 shows no change is driving a car to such a place.

Table 8. "How likely are you to drive a car to an occasion where alcohol will be served within the next three years?" 1998 and 2001. Percent.

<table>
<thead>
<tr>
<th></th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most likely</td>
<td>39</td>
<td>37</td>
</tr>
<tr>
<td>Quite likely</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>A little likely</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>A little unlikely</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Quite unlikely</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Most unlikely</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Teetotaler – question not asked</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Not sure</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

As a consequence of the reduced BAC limit, designating a driver not to drink alcohol and drive the others home from places where alcohol is served, should be expected to increase. Table 9 shows, however, no change is designating a driver.
Table 9. “How usual is it among the people you know to designate a driver not to drink alcohol and drive home from occasions where alcohol is served?” 1998 and 2001. Percent.

<table>
<thead>
<tr>
<th>Designating a driver not to drink alcohol</th>
<th>1998</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happens always when alcohol is served</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>Happens often when alcohol is served</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Happens sometimes when alcohol is served</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Happens rarely or never when alcohol is served</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>I never go to places where alcohol is served</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>100</td>
</tr>
<tr>
<td>N</td>
<td>3001</td>
<td>3001</td>
</tr>
</tbody>
</table>

3.6 Changes from 1998 to 2001

The following factors have changed from 1998 to 2001:
- Knowledge of the legal BAC limit. The same percentage knew the new limit in 2001 and the old limit in 1998.
- Knowledge of the amount of alcohol required reaching the limit. Approximately the same percentage answered correctly in 1998 and 2001.
- Knowledge of penalty for driving with a BAC of 0.03 percent.
- Social norm for driving after drinking one bottle of beer.
- The amount of alcohol accepted by oneself before driving.

The following factors have not changed:
- Subjective risk of apprehension.
- Knowledge of penalty for driving with a BAC of 0.07 percent.
- Social norm for driving after four bottles of beer (have changed a little in the opposite direction).
- Likelihood of driving with a BAC below, but not above 0.05 percent.
- Likelihood of driving with a BAC above 0.05 percent.
- Likelihood of driving a car to an occasion where alcohol is served.
- Designating a driver to drive home from occasions where alcohol is served.

4 Discussion and conclusion

4.1 Why no change in drinking and driving?

The most surprising of the results described in chapter 3 is perhaps that the likelihood of driving with a BAC below or above the old BAC limit of 0.05 percent has not changed even
though the amount people would drink before driving has changed and the social norm of
driving after one bottle of beer has also changed. However, only 1 per cent of the interviewees
said in 1998 that they would drive after drinking two bottles of beer or more, which is what it
takes to get considerably above the 0.02 limit. This fact shows that the potential for
improvement was diminutive before the reduction of the legal limit.

4.2 The cause of the observed changes

As there is no control group not affected by the reduced BAC limit, it is impossible to claim
that the changes observed are caused by the legal amendment. However, the changes in
knowledge about the limit, the penalties and the amount of alcohol it takes to get to the limit,
could hardly be caused by other factors than the publicity created by the amendment.

The changes in the social norm and the amount of alcohol the drivers themselves accept to
drink before driving can of course be caused by other factors. However, the norm for driving
after four bottles of beer, which was illegal even before the amendment, has not changed, a
fact supporting the hypothesis that the change in the norm for driving after one bottle of beer
is in fact caused by the amendment. The change in the amount of alcohol the drivers
themselves would drink before driving, is most likely caused by the change in the norm. It
may of course be due to other factors, though no other likely factors are evident.

4.3 Was the reduced limit successful?

The first hypothesis is that the new BAC limit will reduce the driving with BACs between
0.02 and 0.05 percent. There is no change in the percentage of license holders saying that they
are at least a little likely to drive with a BAC below, but not above the former limit of 0.05 per
cent. Consequently the first hypothesis has to be rejected. However, the percentage claiming
that they will drink no alcohol before driving has increased by 8 percent.

The second hypothesis is that the new limit will also reduce the driving with BACs above 0.5
percent. There is no significant change is the percentage of license holders saying that they
are likely to drive with a BAC above 0.05 per cent. The number of persons saying that they
will drink two bottles of beer or more, i.e. the amount it takes to get to the 0.05 limit, is so
small that significant changes cannot be measured by the method used in this project. Thus,
the second hypothesis has to be rejected as well.

The objective of the reducing driving with BACs below or above 0.05 per cent has not been
achieved so far. However, the after-survey was carried out less than six months after the
amendment came into effect. Another explicit objective of the amendment was “to
demonstrate that driving of a motor vehicle and the consumption of alcohol do not belong
together.” (Odelsting Proposition 26 (1999-2000). In terms of this objective the amendment
may be considered successful as the social norm of driving after only one bottle of beer has
become stricter and more people claim that they drink no alcohol before driving.

The most important question whether or not the reduced limit will reduce the number of
alcohol-related road accidents cannot be answered by the kind of data presented in this paper,
and it is also too early to say. Bernhoft and Behrens dorff (2000) have shown that even if
drinking and driving was reduced in Denmark by a reduced BAC limit, the number of
alcohol-related accidents need not be reduced. If no reduction of alcohol-related accidents is
observed in Norway, the question could be asked whether the reduced BAC limit is a
necessary restriction on Norwegian drivers.

10
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Vaas, K. & Elvik, R. Føreres kunnskap om og holdning til promillelovgivningen (Drivers’ knowledge about and attitudes towards legislations regulating drinking and driving). Oslo. Institute of Transport Economics. 1992
Session 8. HUMAN PERFORMANCE AND EDUCATION

Identifying subgroups of road users for countermeasure development: Two Australian examples
Teresa M. Senserrick, Monash University, Australia

Attitudes, risk behaviour and accident involvement among Norwegian drivers
Hilde Iversen, Norwegian University, Norway

Attitudes towards traffic safety, risk perception and behaviour among young drivers and their passengers
Torbjörn Rundmo, Norwegian University, Norway

The influence of sight distance for the speed of vehicles and road safety – Inquiry and comparison in different European countries
Klaus Habermehl, Fachhochschule Darmstadt, Germany

The TRAINER project – development of a new cost-effective Pan-European driver training methodology and how to evaluate it
Torbjörn Falkmer, VTI, Sweden

The effects of diabetes and low blood sugar levels on driving behaviour: comparison of diabetics and non-diabetics.
Marike H. Martens, TNO Human Factors, The Netherlands

The effect of traffic flow improvements on driver attitudes towards pavement markings and other traffic control devices, and pedestrian safety
David Robinson, Fayetteville State University, USA
IDENTIFYING SUBGROUPS OF ROAD USERS FOR COUNTERMEASURE DEVELOPMENT: TWO AUSTRALIAN EXAMPLES

Teresa M. Senserrick
Monash University Accident Research Centre, Australia, tel: +613 9905 1923

Cluster analysis is a statistical classification technique that can identify subgroups of people with similar profiles on a research measure or measures. Given its exploratory nature, cluster analysis has a somewhat controversial history in traffic safety research. It has been argued that the ability to produce different solutions using different methods reduces the credibility of cluster analysis as a useful measure for traffic safety research. Part of the problem has been the inconsistent selection of clustering techniques by researchers. This is true even though studies of biological data with known structures have identified and recommended particular methods to apply to particular types of data. In addition, many validation techniques have been developed to test selected solutions. This paper presents an overview of these issues, including two recent Australian studies that have including cluster analyses; one relating to seatbelt use and the other to speeding behaviour. The studies also used factor analysis to first reduce the amount of variables entered into the cluster analysis. In this way multiple measures could be included. It is argued that this combination, factor analysis followed by cluster analysis, can provide a powerful exploratory tool for traffic safety research. Keywords: countermeasures, cluster analysis, factor analysis, speeding, seatbelts, attitudes, behaviours

Cluster Analysis as an Exploratory Research Tool

Cluster analysis is an exploratory research tool that can classify people who score similarly on a research measure or range of measures into several groups or clusters. The technique aims to minimise variance within each cluster and to maximise the variance between clusters. In road safety research, cluster analysis can offer a practical solution to identifying different subgroups of road users for countermeasure development.

For example, Wieczorek and Miller\(^1\) identified five types of drivers who had been convicted for drink-driving and matched appropriate treatments for the different groups. The five clusters replicated earlier work by Donovan and Marlatt\(^2\) and Steer, Fine and Scoles\(^3\). However, cluster analysis has not been readily received in road safety research. This has been particularly due to the finding that applying different clustering techniques can generate different solutions for the same set of data.\(^4\,5\) As a ‘best fit’ technique with no universally accepted statistical significance test, cluster analysis has been criticised as being vulnerable to misuse and confirmatory bias.\(^6\,7\)

Part of the problem is that road safety researchers have been inconsistent in their choice of clustering techniques, even when examining the same issue.\(^1\,3\,8\) This is true even though studies of biological and other data with known structures or taxonomies have identified and recommended particular methods to apply to particular types of data. In addition, many validation techniques have been developed to test selected solutions. The following sections address these issues.
Choice of Clustering Approach

Different clustering approaches have been developed to suit different types of data, including different measures of similarity or dissimilarity between cases and different techniques to cluster the multiple pairs of cases. Several considerations and a widely recommended two-step clustering approach that generated useful solutions in two recent Australian road safety studies, are detailed below.

Preparing data for analysis
While Everitt\textsuperscript{9} and others\textsuperscript{10,11} have cautioned that standardising variables may dilute the effect of the best discriminators, more recently Everitt\textsuperscript{12} and also Romesburg\textsuperscript{13} recommended the use of standardised scores to remove arbitrary effects and to allow each variable to contribute equally. In particular, variables should be standardised when some have a greater range of variation than others\textsuperscript{14}. This recommendation has generally been adopted in road safety research that has used multiple measures.\textsuperscript{1,4}

It is also widely accepted that most clustering techniques are sensitive to outliers.\textsuperscript{12} An extreme value can dramatically shift a cluster centroid or form a non-representative cluster. Therefore, it is best to carefully screen clustering data before performing the analysis and to consider whether removal of outliers is appropriate according to the measure and research aims. Notably, missing values can generally be managed by most software packages.\textsuperscript{15}

Choice of clustering method and similarity-dissimilarity measure
As a first step, a hierarchical clustering method is recommended, with Ward’s\textsuperscript{16} the preferred method. Ward’s method is based on the principle that the loss of information that results from grouping cases can be measured by the total sum of squared deviations of each case from its closest cluster centroid. Each possible pair is considered and the union that results is the minimal increase in the error sum of squares, that is, the minimum information loss. This method ensures minimum variance within each cluster and maximum variance between clusters. Ward’s method has been widely recommended as providing the optimal or near optimal solution.\textsuperscript{13,17-19}

Most clustering techniques use a matrix of similarity or dissimilarity between cases.\textsuperscript{12,13} Squared Euclidean distance is the most widely used and recommended measure of similarity-dissimilarity, particularly in association with Ward’s method.\textsuperscript{1,4,12,13,19} The squared Euclidean distance measure computes the distance between each pair of cases for each clustering variable. The differences are squared and summed, then the total sum is squared.\textsuperscript{20} Overall and colleagues\textsuperscript{19} reported on an extensive study in which 35 cluster analysis methods were contrasted. Ward’s method used with Euclidean distance was found to perform best on all indicators.

Refining the solution
The use of clustering techniques that make only a single run through the data has been criticised for not allowing relocation of cases that may have been poorly classified.\textsuperscript{21} Relocation procedures maximise between-group variance and minimise pooled within-group variance, thereby ‘sharpening’ the solution.\textsuperscript{9,22} Therefore, it is recommended that cluster data generated by Ward’s hierarchical method be subject to a k-means relocation analysis known as quick cluster.
Quick cluster analysis updates cases to cluster centroids in successive iterations until the solution stabilises, that is, until there is no further reassignment of cases in successive iterations. The cluster centroids of the final solution describe the profile for each cluster. Again, squared Euclidean distance is recommended as the similarity-dissimilarity measure.

While quick cluster analyses can be applied when the number of initial groups or cluster centroids is unknown, it has been cautioned that this approach often results in suboptimal solutions. The use of the two-step approach, first, using a hierarchical method to determine the number of clusters and initial cluster centroids, second, a relocation method to optimise the solution, is the most widely recommended approach. Wieczorek and Miller applied this two-step approach for their research on treatment applications for subgroups of drink drivers.

Statistical checks
In order to check the validity of the solution and to clarify that each clustering variable contributes to the solution, ANOVA can be performed for each clustering variable. While Hartigan cautioned that clusters are computed to be separate groups and therefore, significant differences across groups for each variable are expected, Romesburg argued that this is a necessary procedure to clarify where the differences are and to assist interpretation. This also allows examination of the magnitude of differences between the clusters; that is, whether they are minimal or substantial.

Further, as a cluster can be defined as a group of cases in which variance among members is relatively small, it is also expected that the standard deviations for each variable for each cluster will generally be lower than the standard deviation for the total sample. This is a quick-and-easy way of identifying the extent of discrimination in the final solution.

Number of Clusters
As with choice of technique, there is no universally accepted method for determining the appropriate number of clusters in a given analysis. Therefore, the recommended practice is to apply more than one method. Several methods are described here.

Graphical representations
When using a hierarchical clustering method such as Ward’s, a dendrogram or cluster tree plot can provide a graphical representation of the hierarchical groupings of cases to clusters. The grouping of each case to successive clusters is presented vertically in a systematic, branch-like manner. With this structure in place, the number of intersections created by a horizontal line drawn across the 'branches' of the diagram at any given point, reveals the number of clusters at that stage of the hierarchy. In this way, it is possible to identify the stages that group substantial numbers of participants together. The dendrogram was the first data summary consulted in the two following studies to determine the appropriate number of clusters for further analyses (see e.g. Figure 1).

Statistical tests
One statistical test that has been used to validate the number of clusters is discriminant function analysis. The percentage of cases correctly classified into the clusters by the discriminating variables gives an indication of the accuracy of the cluster solution. While discriminant function analysis also includes a test of significance not available in cluster analysis, its use has been criticised as misleading. While the analyses are independent, the
cluster analysis output is used as the discriminant function analysis input and therefore, the data are not. Therefore, the discriminant function analysis test is expected to be significant as a necessary validation of the number of clusters. The test alone is not a sufficient test of significance. It is the percentage of cases correctly classified that shows appropriate fit of the data and validates the choice of clusters.\textsuperscript{32}

Interpretability and usefulness of the solution

Finally, some researchers have argued that interpretation, usefulness, and simplicity of the cluster solution are most important and that the number of clusters should be decided based on this principle.\textsuperscript{9,28,38-40} Interpretation is based on the profile presented by the mean scores or centroids for each cluster. The usefulness of the chosen solution may not only be verified by the researcher but by experts in the applied field who have working knowledge of the relationships under consideration.\textsuperscript{13,41-43}

In sum, when carefully applied, with choices justified and solutions confirmed in several ways, cluster analysis can provide a valuable technique for identifying subgroups of road users.

The above approach was applied in two recent Australian studies. Both were based on telephone surveys of approximately 1000 drivers in Victoria, Australia. Both were proceeded by a factor analysis to identify any underlying response patterns and to reduce the number of clustering variables. (Note that this is not necessary as cluster analysis can be performed on a large number of variables; however, this can sometimes make interpretability difficult.) Factor analysis is a particularly useful procedure for road safety research as normality of variables need not be assumed and road safety attitudes are often skewed towards positive responses. Factor analysis is sensitive to outliers however, and these were excluded. Principal Components Analysis was used to extract factors with eigenvalues $\geq 1$ and scree plots were examined to confirm the optimal number of factors. Solutions were subject to oblique rotation and alpha coefficients were examined as a check of reliability. The following sections present a summary of the results.

Example A

The first study aimed to identify groups of drivers who responded similarly to survey items regarding seatbelt-related attitudes and behaviours. Australia and Victoria in particular has a high rate of seatbelt use.\textsuperscript{44,45} Therefore, it was of interest whether cluster analysis could distinguish meaningful subgroups among respondents.

Method & analysis of clustering variables

The sample was 53.9% female and ages ranged from 17-90 years ($M = 44.9; SD = 15.6$). A factor analysis was performed using 19 items (see Table 1). Each item was rated for agreement on a 0-10 scale, where 0 = do not agree at all, 10 = agree very strongly, and 5 = agree somewhat. Results suggested that responses were based on three underlying patterns or perceptions (accounting for 41.1\% response variance).

A first factor, \textit{Personal seatbelt attitudes & behaviour}, grouped together all items concerning the respondents’ pattern of seatbelt use and related attitudes. High scores on this factor corresponded to regular seatbelt use and positive attitudes towards personal seatbelts use. All items of the second factor, \textit{Perceptions of driving ability}, related to the respondents’ perceptions of their driving ability in relation to others, particularly drivers of the same age.
Table 1: Summary of Three Factors Underlying Seatbelt-Related Attitudes and Behaviours

<table>
<thead>
<tr>
<th>Factor</th>
<th>Items</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor I</td>
<td></td>
<td></td>
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<tr>
<td>(α = .70)</td>
<td>Wearing a seatbelt is automatic for me</td>
<td>.85</td>
<td></td>
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<tr>
<td></td>
<td>I always wear a seatbelt when driving</td>
<td>.84</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I always wear a seatbelt on short trips</td>
<td>.75</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Sometimes I have to remind myself to put my seatbelt on</td>
<td>-.68</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I always wear my seatbelt when driving in a carpark</td>
<td>.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wearing a seatbelt is sometimes a hassle</td>
<td>-.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I always wear my seatbelt when reversing the car</td>
<td>.48</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I sometimes forget to wear my seatbelt when I am a passenger</td>
<td>-.45</td>
<td></td>
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<tr>
<td></td>
<td>I feel very uncomfortable without a seatbelt on</td>
<td>.43</td>
<td></td>
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<tr>
<td>Factor II</td>
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<tr>
<td>(α = .78)</td>
<td>I am a more skilful driver than other drivers my age</td>
<td>.84</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I am safer than other drivers my age</td>
<td>.82</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I am more careful than other drivers</td>
<td>.70</td>
<td></td>
<td></td>
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<tr>
<td>Factor III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(α = .39)</td>
<td>I tend to drive faster than most other drivers</td>
<td>.63</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>It's annoying seeing children in cars without their seatbelts on</td>
<td>-.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It's annoying seeing other adults driving without their seatbelts on</td>
<td>-.51</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Road safety is one of the most important issues in the community</td>
<td>.31</td>
<td>-.49</td>
<td></td>
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<tr>
<td></td>
<td>I am generally a forgetful person</td>
<td>.33</td>
<td></td>
<td></td>
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</tbody>
</table>

Note: displays correlation coefficients ≥ .4

High scores on this factor indicated favourable perceptions of one’s driving skill, safety, and carefulness when driving. A final factor Other driving attitudes and behaviours, appeared to represent other driving and road safety issues, including speed and others’ use of seatbelts. Low scores on this factor indicated more positive attitudes and behaviours in regard to road safety.

Identifying types of respondents
Cluster analyses of factor scores identified a three-cluster solution as optimal. A discriminant function analysis confirmed the presence of three discriminant functions with a combined $\chi^2_{38} = 1661.25$, $p = .000$, for which 95.7% of cases were correctly classified. A MANOVA of the cluster centroids was significant [$F_{3, 1638} = 69.2$, $p = .000$]. Given that the overall model for the three-factor solution was significant, oneway ANOVAs were performed using Scheffé comparisons for each factor in order to identify the sources of differences between the clusters. (Scheffé comparisons protect against Type I error and are considered to be one of the most conservative comparisons.) Results for the analyses are displayed in Table 2. Each factor contributed significantly and revealed meaningful differences between the clusters. (Cluster profiles are represented by column scores and are contrasted by comparison of row scores.)

Cluster 1: Committed seatbelt users with strong positive driving attitudes and behaviours, and high perceptions of their driving ability. The first cluster profile scored above average on all three factors and highest on the factors representing perceptions of driving ability and other driving attitudes and behaviours. This profile reflects a strong commitment to seatbelt use and road safety, both in attitudes and behaviours, and a strong positive perception of personal driving ability in relation to others. This was the largest group with 397 drivers (159 male, 236 female, 2 unknown).
Table 2: Summary of Three-Cluster Classification of Seatbelt Factors

<table>
<thead>
<tr>
<th></th>
<th>Total (N = 858)</th>
<th>Cluster 1 (n = 397)</th>
<th>Cluster 2 (n = 329)</th>
<th>Cluster 3 (n = 132)</th>
<th>F statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal seatbelt</td>
<td>9.33</td>
<td>9.63*</td>
<td>9.65*</td>
<td>7.63^</td>
<td></td>
</tr>
<tr>
<td>attitudes and behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$F_{(2, 855)} = 570.50, p &lt; .000$</td>
</tr>
<tr>
<td>Perceptions of driving ability</td>
<td>7.29</td>
<td>8.54 a</td>
<td>6.13 c</td>
<td>6.44 b</td>
<td></td>
</tr>
<tr>
<td>$F_{(2, 854)} = 455.89, p &lt; .000$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other driving attitudes and behaviours</td>
<td>8.34</td>
<td>9.06 a</td>
<td>8.03 b</td>
<td>6.92 c</td>
<td></td>
</tr>
<tr>
<td>$F_{(2, 855)} = 275.80, p &lt; .000$</td>
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</tr>
</tbody>
</table>

Note: Identical superscripts indicate that row means are significantly different from each other.

Cluster 2: Committed seatbelt users with good driving attitudes and behaviours, but lower-than-average perceptions of their driving ability. This group of respondents scored equally high with those of Cluster 1 on the factor representing positive seatbelt attitudes and behaviours. They also scored reasonably high, although below average, for other driving attitudes and behaviours. However, this group scored the lowest on perceptions of their driving ability. Overall, this profile represents a strong commitment to seatbelt use, general support for other road safety issues, together with a mild regard only for their driving ability. This was also a large group comprising 329 drivers (140 male, 189 female).

Cluster 3: Less-committed seatbelt wearing and driving attitudes and behaviours with lower-than-average perceptions of their driving ability. The final cluster scored below average on all three factors, therefore showing the lowest regard for seatbelt use and other road safety issues of the present sample of drivers. Respondents in this group also perceived their driving ability at a below average level, although somewhat higher than drivers in Cluster 2. Therefore, this group reflected the least committed approach to seatbelt use and other road safety issues, and a mild regard for their driving ability. There were 132 drivers (82 male, 49 female, 1 unknown) in this group — therefore, a smaller group with less than half the number of drivers of the first two groups.

For simplicity and ease of comparison, these three groups are described as those with good, intermediate, and poorer road-safety profiles, respectively. Chi-squared analyses revealed that sex [$\chi^2_{(2)} = 20.8, p < .000$], age [$\chi^2_{(4)} = 25.49, p = .000$], and licence type [$\chi^2_{(4)} = 17.3, p < .01$] differences existed between clusters. Examination of standardised adjusted residuals confirmed that drivers with a good road-safety profile were statistically more likely to be female (2.3), to be in the oldest age group (3.1; 51-90 year olds), and to have a full licence (3.4). In contrast, drivers with a poorer road-safety profile were far more likely to be male (4.5), to represent the youngest age group (3.3; 17-25 years) and to hold a probationary licence (3.0).

In addition, drivers with good and intermediate road-safety profiles spent a greater percentage of time driving in daylight hours ($M_s = 82.0\%$ & $80.4\%$ respectively) than drivers with poorer profiles ($M = 74.3\%$; $F_{(2, 855)} = 7.52, p = .001$). This was a particularly important finding given that drivers in this younger age group are more likely to be involved in injury crashes during these hours than are drivers of the other two age groups (based on Victorian Police crash data). Therefore, the younger drivers in this group are particularly compromising their safety if driving during non-daylight hours without a seatbelt. It is important to note however, that while this group of drivers, showed a less positive score on the seatbelt-related factor compared to the other two groups, the score was still well above the moderate response range...
(7.63 from a possible 0-10). Therefore, it is likely that this group of drivers quite often uses their seatbelts, but does so inconsistently.

It was concluded that cluster analysis generated meaningful distinctions among the respondents. By identifying a particular subgroup of drivers with a poorer road safety profile, countermeasures could be more appropriately targeted at this particular type of driver.

Example B

The second study was designed to inform Victoria Police on current perceptions of overt and covert aspects of their speed enforcement program, including perceptions of risk of detection, and speed-related skills, attitudes, and behaviours. This was to act as a baseline measure to compare responses after introduction of a more covert program.

Method & analysis of clustering variables

The sample consisted of 561 females (56%) and 439 males of several different age groups: under 20 \((n = 30)\), 20-29 \((n = 161)\), 30-39 \((n = 222)\), 40-49 \((n = 212)\), 50-59 \((n = 166)\), and 60+ years \((n = 206)\); (3 refusals). Agreement ratings on the same 0-10 scale were made for 57 items grouped into five sections (see Table 3).

The items in these sections were subject to factor analyses, applying the same conditions as in the first study (see Table 3). Where appropriate, factors were reverse coded so that higher scores indicated more positive responses (e.g. speeding behaviour items). The resulting 14 factors were then included in a second factor analysis to reduce further the number of clustering variables and to enhance ease of interpretation (see Table 4). Five factors were identified with a combined explained variance of 57.2%.

High scores on the first factor represented a belief that detection is easily avoided, few Police cars are seen on the road, and that Police catch very few traffic offenders. For the second factor, high scores suggested a belief that speed enforcement helps lower the road toll, in general is somewhat covert, would be more effective in slowing down drivers if more overt, that speeding is wrong, causes accidents, and that the respondent is uncomfortable driving fast. Low scores on the third factor indicated negative speed-related behaviours, concern with crashing and being at fault in a crash, and daydreaming when driving. High scores on the fourth factor reflected a positive perception of one's driving ability, a belief that traffic offence penalties are severe and personal risk of detection high, that general driving decision-making processes are largely automated, and that the respondent makes positive decisions concerning speed choice and speed awareness. Finally, high scores on the fifth factor represented a view that enforcement programs are overt, but would be more effective in detecting speeders if they were more covert.

Notably for the Police, low visibility of Police vehicles was related to perceptions that enforcement levels were low, rather than covert. This implies Police may be perceived as detecting many offenders when they are more visible, supporting general deterrence theory and also that, during a covert operation, issuing of fines would need to be high, at least initially, in order for the specific deterrence approach to be effective.
Table 3: Summary of Factors Underlying Perceptions of Enforcement

<table>
<thead>
<tr>
<th>Section</th>
<th>General factors influencing decision-making processes when driving (50.1% variance)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>I do not have to think consciously about using the indicators</td>
<td>.82</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I do not have to think consciously about using the accelerator</td>
<td>.81</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I do not have to think consciously about looking out for hazards</td>
<td>.76</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I do not have to think consciously about steering the car</td>
<td>.74</td>
<td></td>
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<tr>
<td></td>
<td>I do not have to think consciously about how fast I am driving</td>
<td>.69</td>
<td></td>
<td></td>
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<tr>
<td>Factor 2</td>
<td>I am a safer driver than other people my age</td>
<td>.85</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I am a safer driver than most other drivers</td>
<td>.84</td>
<td></td>
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<td></td>
<td>I often respond to hazards before I really notice them</td>
<td>.47</td>
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<td></td>
<td>I drive within the road rules</td>
<td>.44</td>
<td></td>
<td></td>
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<tr>
<td>Factor 3</td>
<td>I worry about crashing when I am driving</td>
<td>.77</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>If I have a crash it is likely to be my fault</td>
<td>.66</td>
<td></td>
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<tr>
<td></td>
<td>I daydream or think about other things when driving</td>
<td>.46</td>
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</table>

<table>
<thead>
<tr>
<th>Section II</th>
<th>Specific factors influencing speed choice decisions (40.5% variance)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>I often drive a little over the speed limit</td>
<td>.75R</td>
<td></td>
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<tr>
<td></td>
<td>I often drive 10 km an hour or more over the speed limit</td>
<td>.65R</td>
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<tr>
<td></td>
<td>I sometimes change my speed without making a conscious decision</td>
<td>.60R</td>
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<td></td>
<td>I slow down at locations where there are sometimes speed cameras</td>
<td>.58R</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I become frustrated when people around me are driving too slowly</td>
<td>.56R</td>
<td></td>
<td></td>
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<tr>
<td>Factor 2</td>
<td>I am always aware of the speed limit</td>
<td>-.40</td>
<td>.60</td>
<td></td>
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<td></td>
<td>I often check my speed when driving</td>
<td>.55</td>
<td></td>
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<td></td>
<td>I make conscious decisions to speed up or slow down</td>
<td>.51</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Current road conditions influence my speed</td>
<td>.49</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>I drive more slowly when it’s raining</td>
<td>.47</td>
<td></td>
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<tr>
<td></td>
<td>I choose a speed and stick to it</td>
<td>.40</td>
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<tr>
<td>Factor 3</td>
<td>Speeding causes accidents</td>
<td>-.75</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Speeding is wrong</td>
<td>-.71</td>
<td></td>
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<tr>
<td></td>
<td>I am comfortable driving fast</td>
<td>.49</td>
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<table>
<thead>
<tr>
<th>Section III</th>
<th>Perceived risk of detection while driving in general (61.4% variance)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor 1</td>
<td>I see very few Police cars on the road when I drive</td>
<td>.83</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>The Police catch very few of the people who disobey traffic rules</td>
<td>.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 2</td>
<td>Overall, the penalties for breaking the law while driving are severe</td>
<td>.80</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>If I break the law while driving, I will most likely be caught</td>
<td>.65</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Summary of Factors Underlying Perceptions of Enforcement (cont.)

<table>
<thead>
<tr>
<th>Section IV</th>
<th>Perceived risk of detection by all types of speed enforcement (40.9% variance)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor I</td>
<td>It’s easy to avoid being caught speeding</td>
<td>.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Even if you’re caught speeding, you can still avoid being fined</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Speed enforcement only happens during the day</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>There’s not much chance of being caught speeding</td>
<td>.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I rarely see any Police cars doing speed enforcement</td>
<td>.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>The penalties for speeding are not severe at all</td>
<td>.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor II</td>
<td>Enforcing the speed limit helps lower the road toll</td>
<td>.69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It’s hard to know where there is speed enforcement happening</td>
<td>.62</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section V</th>
<th>Perceived risk of detection by speed camera enforcement only (42.5% variance)</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor I</td>
<td>Speed cameras are usually well hidden</td>
<td>-.71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>It’s hard to predict where there are the speed cameras</td>
<td>-.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speed cameras are easy to see</td>
<td>.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speed cameras always operate at the same locations</td>
<td>.52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor II</td>
<td>There’s not much chance of being caught speeding by a speed camera</td>
<td>.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I don’t see as many speed cameras these days as I used to</td>
<td>.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Even if a speed camera catches you, you can still avoid being fined</td>
<td>.57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enforcement with a speed camera only happens during the day</td>
<td>.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I rarely see any cameras doing speed enforcement</td>
<td>.54</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>My experience tells me that it’s easy to avoid being caught by a speed camera</td>
<td>.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor III</td>
<td>I think speed cameras would slow people down more effectively if they were in full view</td>
<td>.68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Enforcing the speed limit with speed cameras helps lower the road toll</td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor IV</td>
<td>Speed cameras are often used from different types of cars</td>
<td>-.42</td>
<td>.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I know of some locations where speed cameras are often set up</td>
<td>.58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I have never seen a speed camera</td>
<td>-.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I think speed cameras would catch more people if they were completely hidden</td>
<td>.45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: displays correlation coefficients ≥ .4
Table 4: Summary of Second Factor Analysis of Perceptions of Enforcement

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor I</td>
<td>Section IV, Factor I</td>
<td>.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section V, Factor II</td>
<td>.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section III, Factor I</td>
<td>.59</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor II</td>
<td>Section IV, Factor II</td>
<td>.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section V, Factor III</td>
<td>.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section II, Factor III</td>
<td>.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor III</td>
<td>Section II, Factor I</td>
<td>-.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section I, Factor III</td>
<td>-.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor IV</td>
<td>Section I, Factor II</td>
<td>.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section III, Factor II</td>
<td>.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section I, Factor I</td>
<td>.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section II, Factor II</td>
<td>.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor V</td>
<td>Section V, Factor IV</td>
<td>.82</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Section V, Factor I</td>
<td>.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: displays correlation coefficients ≥ .4

Identifying types of respondents
Cluster analyses indicated that a four-cluster solution was evident. This was confirmed by the presence of four discriminant functions with a combined $\chi^2(3) = 552.47$, $p < .000$, for which 96.3% of cases were correctly classified. The results of the ANOVAs to identify the sources of differences between clusters appear in Table 5.

Table 6: Means and ANOVA results of second order factor scores by cluster membership

<table>
<thead>
<tr>
<th>Factor: Central themes</th>
<th>Total ($N = 999$)</th>
<th>Cluster I ($n = 215$)</th>
<th>Cluster II ($n = 271$)</th>
<th>Cluster III ($n = 234$)</th>
<th>Cluster IV ($n = 280$)</th>
<th>$F$ statistics ($p = .000$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor I: General detection avoidance, effectiveness</td>
<td>5.10</td>
<td>4.22$^a$</td>
<td>6.43$^b$</td>
<td>5.37$^c$</td>
<td>4.25$^a$</td>
<td>$F_{(3, 978)} = 193.3$</td>
</tr>
<tr>
<td>Factor II: Attitudes, generally covert, overt reduce speeds</td>
<td>7.22</td>
<td>7.82$^a$</td>
<td>7.76$^a$</td>
<td>5.61$^b$</td>
<td>7.59$^a$</td>
<td>$F_{(3, 987)} = 231.0$</td>
</tr>
<tr>
<td>Factor III: Speed-related behaviours, role in crashes</td>
<td>5.55</td>
<td>7.15$^a$</td>
<td>5.99$^b$</td>
<td>5.30$^c$</td>
<td>4.11$^d$</td>
<td>$F_{(3, 996)} = 304.5$</td>
</tr>
<tr>
<td>Factor IV: Personal driving ability, detection avoidance</td>
<td>6.28</td>
<td>6.54$^a$</td>
<td>6.09$^b$</td>
<td>5.63$^c$</td>
<td>6.81$^a$</td>
<td>$F_{(3, 989)} = 57.0$</td>
</tr>
<tr>
<td>Factor V: Cameras overt, covert increase detection</td>
<td>6.21</td>
<td>6.93$^a$</td>
<td>5.05$^b$</td>
<td>6.83$^a$</td>
<td>6.28$^c$</td>
<td>$F_{(3, 959)} = 116.8$</td>
</tr>
</tbody>
</table>

Note: Identical superscripts indicate means are significantly different from each other

Cluster I: Positive profile (79M, 136 F). These drivers who perceived general risk of detection as low, but personal risk of detection as high, reported positive speed-related attitudes and behaviours (well above average), and rated their driving ability as somewhat above average. While they perceived general speed enforcement as covert, camera
enforcement was perceived as more overt. They believed that more overt speed enforcement would slow down drivers more effectively, and that more covert speed camera use would detect more speed offenders.

Cluster II: Very positive profile (108 M, 163 F). This group believed general risk of detection was high, but personal risk low. They reported positive speed-related attitudes and behaviours, and rated their driving ability somewhat below the average. They believed speed enforcement, especially by camera, was covert, and that more overt programs would reduce speeds, but did not agree that more covert programs would detect more speed offenders.

Cluster III: Negative profile (124 M, 110 F). These respondents perceived enforcement (including camera), as very overt, general risk of detection as higher than average, but personal risk as below average. They reported negative speed-related attitudes and behaviours, and a below-average rating of their driving ability. While these drivers did not believe that more overt speed enforcement would slow down drivers more effectively, they did believe that more covert speed camera use would detect more speeding drivers.

Cluster IV: Very negative profile (128 M, 152 F). This group perceived enforcement levels and risk of detection generally as quite low, while rating personal risk and driving ability quite high. They reported positive speed-related attitudes, yet the most negative behaviours. Enforcement was viewed as generally covert, but cameras as somewhat overt. They believed more overt camera operations would slow down drivers more effectively, and that more covert programs would detect more speeding drivers.

Profiles of the four groups of drivers
Sex $[\chi^2(3) = 14.50, p < .01]$ and age $[\chi^2(15) = 78.21, p < .000]$ were found across clusters. Standardised adjusted residuals indicated Cluster I drivers were more likely to be female (2.4) and far more likely to represent 60+ year olds (4.5; $n = 68$). Cluster II, somewhat equally represented males and females and most age groups, although was less likely to represent 20-29 year olds (-2.8; $n = 29$). Cluster III, was more likely to represent males (3.2) and much more likely to represent 20-29 year olds (3.9; $n = 57$). Cluster IV, somewhat equally represented males and females and was more representative of drivers under 20 years (3.1; $n = 16$) and 20-29 years (2.5; $n = 58$).

Therefore, two subgroups were identified as prone to speeding and two as less-inclined to speed. For those less inclined to speed, one subgroup represented more females and drivers of 60+ years of age, while the other represented both male and female drivers and every age group except that of 20-29 year olds. This latter age group was most represented by the two subgroups that were more inclined to speed. This age is a significant one, given that this usually covers the period when probationary drivers receive a full licence, increasing their legal BAC from .00 to .05g/100ml. Therefore, the interaction of both speed and drink driving issues is important to explore for this age group.

One of these speeding subgroups was predominantly male. These drivers believed speed enforcement was overt and that detection was avoidable. It is probable that these drivers would be the most likely to change their speeding behaviour if speed camera operations became more covert and they experienced greater risk of detection. The second subgroup was represented somewhat equally by males and females and moreso by under 20 year olds (in addition to 20-29 year olds). These drivers were prone to speeding behaviour even though they perceived personal risk of detection as high. It is likely that this group represented the
type of driver previously identified in the literature as prone to speeding regardless of safety or penalties. This confirmed that the learner and probationary periods are important ones to target regarding the personal dangers of speeding, and that methods other than enforcement (e.g. targetted emotive advertising) may be necessary to achieve behavioural change.

Regarding the overt and covert nature of Police enforcement programs, results indicated that both were perceived as potentially generating positive outcomes. In relation to general speed enforcement, it was believed that more overt programs would slow people down more effectively. In relation to speed camera enforcement, it was believed that more covert programs would detect more speeding drivers.

Overall therefore, cluster analyses generated meaningful distinctions that provided valuable information for the Police, road safety organisations and researchers alike. The inclusion of multiple measures allowed combinations of variables to be considered simultaneously and offered rich profiles of driver subgroups that could benefit Police enforcement planning, countermeasure development, and better targetted research.

It is recommended that road safety researchers further explore the use of cluster analysis in an in-depth, systematic manner that will enhance the perceived validity and reliability of the technique and allow stronger conclusions to be drawn regarding the exploratory findings that result.

References

ATTITUDES, RISK BEHAVIOUR AND ACCIDENT INVOLVEMENT AMONG NORWEGIAN DRIVERS

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Tlf.: + 47 95 29 55 68

Abstract
Increasingly, professionals on safety and risk issues are becoming aware that there are occasions when people’s attitudes and behaviour towards risk and hazard has to be changed. This paper attempts to identify determinants of risk behaviour and accident involvement in traffic, with the aim of developing effective accident countermeasures. Several studies have related risk behaviour to traffic safety issues like collision risk and accident rates, but the relationship between accidents and preceding behaviour is still largely unclear. Attitude change is often hypothesised as a way of changing road user behaviour. However, correspondence between measured dispositions and overt actions is not a simple matter, and more research is needed addressing this issue in road safety research. Examination of associations between attitudes, risk behaviour and involvement in near misses and accidents can help develop more adjusted and effective traffic safety interventions by early identification of those more likely to be involved in accidents. A major challenge is to find measures that influence the groups of high-risk recipients more efficiently. This study is based on a self-completion questionnaire survey carried out among a representative sample of Norwegian drivers1. The sample was representative of the Norwegian public and collected in year 2000 and 2001 (n=2614), with a 50% response rate. The questionnaire included measures of attitudes, risk behaviour, reactions from others and involvement in near accidents and accidents. Results showed that attitudes towards traffic safety issues were associated with involvement in risk behaviour in traffic, especially attitudes towards rule violations and speeding. In addition, risk behaviour had a direct effect on the reactions drivers receive from others in traffic and both involvement in near misses and accidents. Near misses and especially reactions from others influenced accident involvement directly.

Introduction
Number of fatal injuries has increased in Norway during the last years. Driver behaviour is considered to play a major role in traffic safety and accordingly behavioural change offers an opportunity for injury reduction (Evans, 1996). The importance of behaviour in the prevention of vehicular accidents has been documented extensively (e.g., Elander et al., 1993; Parker et al., 1995) and has led to attempts to encourage a variety of safe driving behaviours (e.g. Juhnke et al., 1995; Martinez et al., 1996). Studies have shown that risk-taking is a major factor underlying high collision risk (Jonah, 1986), and that self-reported violations predict accident rates (Parker et al., 1995; West et al., 1993). Manstead et al. (1992) found associations between major deviations from average traffic speed and increases in crash risk (Parker et al., 1992). Drivers who scored high on violations and errors were more likely to be involved in accidents, than those who scored high on lapses (Reason et al., 1990; Parker et al., 1995). Drink driving behaviours also make contributions to driver risks and are associated with increased rates of risky driving behaviour, motor vehicle accidents and morbidity from these accidents (Evans, 1991). Alcohol consumption leads to decreased reaction time, poorer eye-hand co-ordination and impaired driver performance (West et al., 1993). However, the association may reflect the fact that individuals engaging in drink driving are characterised by other behavioural tendencies, independently of alcohol consumption (Hedlund, 1994; West, 1995), like tendencies to risk taking and antisocial behaviour patterns that may include risky driving behaviours (West, 1996). Horwood et al., (2000) suggested drink driving as one of a constellation of risky driving behaviours that may include speeding, unsafe and careless driving and that higher rates of accidents reflects a general tendency to risky driving rather than the specific effects of alcohol on driver performance.

To summarise thus far, several studies have proven successful in relating risk behaviour to traffic safety issues, like collision risk, crash risk and accident rates. Considering these results, it is expected that drivers with a high score on self-reported risk behaviour will be more involved in accidents than others. However, performance aspects as well as motivational aspects, individual differences and momentary state variables

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1 This study was financed by the Director of Public Roads’ Research Programme on traffic safety
should also be encompassed when developing models and theories for the relationship between behaviour and traffic safety.

Given that most violating behaviour is the result of a conscious decision taken by the driver, it follows that it is useful to explore attitudes and motivation which lead to a decision to perform a certain behaviour. What complicates attitude measurement is that behaviour is not always consistent with attitudes. In general the correlation has been rather low, a review of 47 studies by Wicker (1969) showed that a great majority of the correlation coefficients were rarely above 0.30 ($R^2 < 0.10$). However, this review only resulted in research using more systematic and comprehensive techniques and a wide range of other variables influencing the relationship were introduced.

Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980) and its extension Theory of Planned Behaviour (TPB) (Ajzen, 1985; Ajzen 1991) is models of determinants of human behaviour, which has generated a great deal of interest. TRA stated that intention to display certain behaviours could be predicted on the basis of attitude towards that behaviour and personal norm concerning the behaviour. In TPB perceived behavioural control was included as a third primary predictor variable (PBC), reflecting degree of perceived control over behavioural performance. Perceptions may not be accurate, but the impact on intentions is not seen as being influenced by accuracy. Higher perceived behavioural control over a positively evaluated behaviour will be associated with stronger intentions to perform the behaviour. Ajzen (1988) stated that broad response dispositions are poor predictors of specific actions, but the relationship between attitudes and behaviour tend to be strong when measures are at the same level of specificity.

A meta-analysis of 88 attitude-behaviour studies revealed that attitudes significantly and substantially predict future behaviour (Kraus, 1995). The correlation was high when measured at corresponding levels of specificity. However, corresponding attitudes and behaviour did not always correlate, similarly, attitudes and behaviour could be highly correlated even when measures did not correspond. Kraus (1995) stressed the importance of research on moderating variables, which specifies the conditions under which consistency will and will not occur. The attitude-behaviour relationship has been the topic of considerable debate (see e.g. Howarth, 1988). It seems that attempts to change beliefs and attitudes would offer a potential method of bringing about behavioural change, but the role of level of specificity, belief accessibility, frequency of past behaviour and moderating variables should also be considered in developing effective intervention campaigns relating attitudes and behaviour.

Lawton et al. (1997) found self-reports of intentions to speed on a motorway to mirror the extent of the problem behaviour fairly accurately. Persistent speeders were not miscalculating risk, but were rather taking the risk deliberately. They made judgements about the degree of speeding that was acceptable on particular roads and behaved accordingly. Lawton et al. (1997) suggested general road safety campaigns aimed specifically at reducing speed as a useful strategy to reduce accidents. West et al., (1993) found accident involvement related to self reported behaviour and social motivation. Other studies have shown correlation between propensity to commit traffic law violations and accident involvement (Parker et al., 1992). Assum (1997) found that accident risk was affected by attitudes when no other factors were considered, both in general and especially according to the indices of responsibility and how one characterises oneself as a driver. However, age and annual mileage turned out to be more important than attitudes, and he concluded that the relationship between attitudes and accident risk is part of a complex web of relations between demographic variables, behaviour variables and most likely, many others. Results from a study by Parker et al. (1998) showed beliefs and attitudes as predictors of self-reported aggressive driving behaviour. However, several explanations are possible. Those who get involved in aggressive driving behaviour develop less negative affective attitudes, and even enjoy the buzz. Respondents with positive affective attitudes may anticipate the buzz, and allow themselves to get into situations were driving incidents are likely. It may be difficult to state whether intentions follow behaviour, or vice versa. In addition, self-presentational issues might affect the results; some choose to present themselves as drivers who commit driving violations, and enjoy it.

Studies indicate that attitude is an important predictor for behaviour in traffic, but evaluations of effects from traffic safety campaigns have concluded that only small changes are found in the target behaviour when trying to change attitudes (Elvik et al., 1997; Aarø et al., 1996). Combinations of different measures can give more significant effects on behaviour (Aarø et al., 1996). A meta-analysis of road safety media campaigns (GADGET, 1999) evaluated effects of safety campaigns in Europe, and provided empirical evidence for the statement that road safety campaigns can help reduce frequency of accidents especially when combined with other measures. The analysis was conducted from 35 studies with 72 results, and only accidents were explored. The overall effect of safety campaigns was estimated to reduce number of accidents by 8.5 % during
the campaign period. For the after-period of campaigns the overall effect was nearly doubled: 14.8%. Results were attributed to all components of the campaign like enforcement, reward, legislation, educational programme, etc., not only to the media campaign itself. The first objective of this paper was to examine the relationship between attitudes toward traffic safety issues and risk behaviour in traffic, expecting respondents with attitudes less focused on safety issues to be more involved in risk behaviour. The second aim was to analyse the relationship between these two factors, near misses, reactions from others (passengers, police etc.) and involvement in accidents. It was hypothesised that drivers who reported high degree of risk behaviour would be significantly more likely to acquire a reactions like warnings from the police, fines or convictions, and also to be more frequently involved in near misses and accidents than those who did not. Reactions from others can also influence ensuing behaviour, but this study focus on the opposite relation.

2. Method
2.1. Sample
The respondents of the present study were a representative sample of the Norwegian population with a driver’s licence. They participated in a mail questionnaire survey carried out in 2000 and 2001. The response rate was 51%, and the final sample comprised a total of 2614 respondents, 48% men and 52% women. They were on average 45 years of age. 44% had a college/university education, 47% work related or senior high school and the remaining junior high school.

2.2. Measures
Three dimensions comprising 18 variables measured attitudes related to traffic safety issues like rule violations and speeding, others driving, combination of drinking and driving etc. (see Table 1). A five-point evaluation scale was applied, ranging from “fully agree” to “fully disagree”. Risk behaviour comprised 26 items related to violations of traffic rules and speeding e.g. reckless driving, not using seat belts, drinking and driving, attentiveness of others (see Table 2). The respondents were asked to assess how often they carried out each of the activities on a five-point evaluation scale, ranging from 1 “very often” to 5 “never”. Reactions from others consisted of five variables measuring frequency of achieved warnings from other passengers, road users or the police and achieved fines or sentences. Registration of accidents was measured by involvement in number of collisions and accidents as a driver. Near misses as a driver, passenger or pedestrian were also reported. A three-point scale ranging from “never” to “several times” measured all items related to reactions, near misses and accidents.

2.3. Statistical analysis
Principal component analysis with iteration and varimax rotation was applied to detect underlying dimensions of attitudes as well as risk behaviour. The Linear Structural Relation (LISREL) analysis program (Jöreskog and Sörbom, 1993) was used for confirmatory factor analysis, and to explore the relationship between attitudes, behaviour, reactions from others, near misses and involvement in accidents. The aim was to examine the fit of the factor models carried out by the exploratory analysis, and to test the goodness-of-fit. Structural Equation Modelling Made Simple (STREAMS) offers a consistent interface to the LISREL program and was used as a support in this study (Gustafsson & Stahl, 2000). Cronbach’s alpha coefficient evaluated the internal consistency of the indices.

3. Results
3.1 Dimensions of attitudes related to traffic safety
The principal component analyses identified three underlying dimensions of attitude. A confirmatory factor analysis showed that no further adjustments were necessary; \( \chi^2 = 10345, \text{ d.f.} = 153, \text{ RMSEA} = .051, \text{ GFI} = .96, \text{ AGFI} = .94 \) (see Table 3). The high value of \( \chi^2 \) must be considered in relation to the large size of the sample. Attitudes towards traffic safety comprised three dimensions with a total of 18 different items. Responses to each dimension were added for further analysis. However, one the core aims of the study were to develop new instruments for measurement, accordingly the majority were items developed for this survey in particular.

\[ \chi^2 = 10345, \text{ d.f.} = 153, \text{ RMSEA} = .051, \text{ GFI} = .96, \text{ AGFI} = .94 \]

\[ A random sample of respondents were selected by the Norwegian Drivers’ Licence Register \]

2
The first factor entitled **Attitude towards rule violations and speeding** comprised statements concerning the need to ignore traffic rules to ensure traffic flow or exceed speed limits to get ahead of “Sunday drivers”. Questions were also related to respect of traffic lights, acceptance of taking chances or speed, or if you consider yourself a good driver (see Table 1). The next factor, **Attitude towards others careless driving** included evaluation of other peoples driving e.g. courage to speak up, riding with someone who speeds, risking life and health by riding with a irresponsible driver. The last dimension questioned respondents **Attitude towards drinking and driving**; if they ever considered driving after consuming alcohol, and if they would ride with a driver they knew had been drinking.

The Cronbach’s α were found to be satisfactory for two of the three indices (see Table 3): the second dimension (α = .620) had a lower α-value than the first (α= .833) and third (α = .836) dimension. A α-value of 0.70 or higher is considered satisfactory (Nunnaly, 1978). In addition, item-analysis was carried out by correlating the corrected sum score for a dimension with each of the single indicators of the dimension. It is expected that the three dimensions all measure attitude towards traffic safety, however, different aspects. A correlation coefficient above 0.30 indicates that each indicator measures the same as the other indicators, and Table 3 shows that all the indicators satisfy this criterion. Analysis of intercorrelations between the three subscales showed that the strongest correlation is between the sub-scales concerning **Attitude towards rule violations and speeding** and **Attitude towards others careless driving** (r = .42). Correlations between the other relations were weaker, indicating less similar dimensions. Consequently, a model separating the items into three dimensions seemed appropriate.

### 3.2 Attitudes towards traffic safety among the Norwegian public

Table 4 shows means and standard deviations for the dimensions measuring attitudes towards traffic safety, and Table 5 shows %ages of “ideal” and “non-ideal” attitudes. There is a question of judgement what are “ideal” and “non-ideal” attitudes; certain attitudes can in different situations induce both safe and unsafe driving behaviour. A total of 11 % of the respondents reported “non-ideal” attitudes related to rule violations and speeding. Only 3 % had “non-ideal” attitudes related to others careless driving behaviour and 4 % related to drinking and driving. The potential of improvement is most important related to the following attitudes: 20 % believed that many traffic rules must be ignored to ensure traffic flow (means and standard deviations for each item are listed in Table 1). Every fifth respondent thought that drivers who break traffic rules not necessarily have more risky driving styles than other drivers, and 23 % considered it acceptable to drive at 100 mph when others were not around. Many (28 %) believed that it make sense to exceed speed limits to get ahead of “Sunday drivers”, 11 % rides with insecure drivers when no other transport options exists, and 3 % with drivers they know have been drinking. These results indicate that despite positive attitudes toward traffic safety issues, there are potentials for improvement, especially related to the violations of rules and speeding.

### 3.3 Dimensions of risk behaviour related to traffic safety

Explorative factor analyses were carried out to examine dimensions of behaviour, and risk behaviour in traffic was measured by 26 different items. STREAMS/ LISREL was applied for a confirmatory factor analysis (see Table 6). Table 6 displays eight underlying dimensions, the total inter-item correlation coefficients and inter-item correlation coefficients for each of the indicators. The factors were entitled **Violations of traffic rules and speeding** (α = .813), **Reckless driving/ funriding** (α = .671), 3. **Not using seat belts**, (α = .677), **Cautious and watchful driving** (α = .665), **Drinking and driving** (α = .444), **Attentiveness of children in traffic** (α = .816), **Discussing traffic safety with others** (α = .616), and finally **Driving below speed limits** (α = .846). Most of the α-values indicated internal consistency for the dimensions, and the fit of the model was also good (RMSEA = .050, GFI = .94, AGFI = .93). Table 7 shows intercorrelations between sub-scales measuring behaviour. The strongest correlation was found between Violations of traffic rules/ speeding and Reckless driving/ funriding (r = .63), indicating similar dimensions. The result suggests that it can be questioned if variables comprising these dimensions were too similar, and measured behaviours too closely related to be separated. However, the dimensions consisted of items representing different aspects of risk behaviour, and it was therefore considered conceptually meaningful to use two dimensions in further analysis. Other sub-scales were moderately to weakly correlated, indicating that risk taking behaviour in traffic are multidimensional.
3.4 Risk behaviour in traffic
Means and standard deviations for the dimensions of risk behaviour are shown in Table 8. Table 9 shows “ideal” and “non-ideal” behaviour. Questioning definitions of “ideal” and “non-ideal” should also be noted related to behaviour in traffic. An example is driving below speed limits. In some situations this behaviour can have a dangerous effect, reducing traffic flow and irritating other drivers. In other situations it is an important adjustment to difficult road conditions and represents cautious and responsible driving. Important areas of improvement are summarised, and means and standard deviations for each item are listed in Table 2. 59 % drive below speed limits, 15 % never discusses traffic safety with others and 12 % are involved in “non-ideal” behaviour related to violation of traffic rules and speedling. Many break 50 mph (31 %) and 80-90 mph (69 %) speed limits with more than 10 mph., and overtake the car in front even when it keeps appropriate speed (35 %). Furthermore, 30 % ignore traffic rules to secure more continuous driving, and more than half of the sample (54 %) drive faster to catch up on appointments, and keep driving when they are tired and realise that they need a break (59 %). Some (21 %) drive short distances without wearing a seat belt.

The present findings illustrate again the importance of focusing on risk behaviour related to speeding and violations of traffic rules. These risk behaviours turn out to be prevalent violations, and studies have shown that risk-taking is a major factor underlying high collision risk, (Jonah, 1986), and that self-reported violations predict accident rates (Parker et al., 1995; West et al., 1993). Associations have been found between major deviations from the average traffic speed and increase in crash risk (Parker et al., 1992). It seems like speeding is both common and regarded with a degree of tolerance.

3.5 Reactions from others and involvement in near misses and accidents
Overall, 15 % of the respondents had experienced traffic accidents where a person had been injured, and 68 % had been involved in one or more collisions where the vehicle was damaged. A large number of the sample had experienced near-accidents, either as a driver (82 %), a passenger (70 %) or a pedestrian (41 %). Only 3 % had been sentenced, and 23 % had been fined related to different situations in traffic. The police or Department of Motor Vehicles had given 15 % of the respondents a warning, and 52 % had received negative reactions from passengers or others while driving.

3.6 The relationship between attitudes and risk behaviour
Structural equation modelling was applied to explore the relationship between attitudes, behaviour, reactions from others, near misses and involvement in accidents. The first model examines the relationship between attitudes towards traffic safety and risk behaviour in traffic (see Figure 1). The exogenous, latent variables were the three dimensions of attitude, and the endogenous, latent variable was risk behaviour. The three predictors explained 41 % of the total variance in risk behaviour. Attitude towards rule violations and speeding was the strongest predictor for risk behaviour ($\beta = 0.59$). Attitude towards drinking and driving ($\beta = 0.23$) was also associated with risk behaviour, but Attitude towards others careless driving ($\beta = 0.08$) did not seem important to explain variations in risk behaviour. The model fit was satisfactory, RMSEA = .10, GFI = .97, AGFI .96.

3.7 Predictors of accidents and near misses in traffic
In the next model it is hypothesised that attitudes, risk behaviour, reactions from others and near misses influence accident involvement. However, as seen in the previous model, attitudes influence behaviour and behaviour can both have a direct and indirect effect on involvement in accidents via reactions from others and near misses. Reactions from others and near misses can also have a direct effect on accident involvement. The results in Figure 2 show that attitudes contributed significantly to the respondents’ risk behaviour ($\beta = 0.86$). Risk behaviour influence the respondents reactions from others ($\beta = -0.51$) but also involvement in near misses in traffic ($\beta = -0.39$), especially as a driver or passenger. Risk behaviour ($\beta = 0.18$), near misses ($\beta = 0.31$) and reactions from others ($\beta = 0.63$) have all a direct effect on accident involvement. Taken together, these variables account for 44 % of the total variance in accident involvement. The model fit was good, RMSEA = .067, GFI = .93, AGFI .90. Identical models were tested using attitudes and reactions as predictors of risk behaviour, and risk behaviour as predictor of near misses and accidents, another linked attitudes directly to accident involvement. Contrary to what we found in the previous model (Figure 2) the results showed a very weak fit, indicating that the model in Figure 2 explains more of the total variance in accident involvement behaviour compared to these models.
4. Discussion
The first aim of this study was to examine whether individuals with a high propensity for risk behaviour had more negative attitudes towards traffic safety issues compared to those who score low on this variable. The results provided further evidence for the contribution to prediction of behaviour made by attitudes. Attitudes towards traffic safety were associated with involvement in risk behaviour, especially attitudes concerning rule violations and speeding and reckless driving. Consequently, changing attitudes represent a potential method of bringing about behaviour change. If beliefs and values, which motivate individuals to behave in particular ways, can be specified, attempts to change that behaviour can be more precisely targeted. Many interventions studies based on this assumption have failed to show any significant effects. One of the reasons can be that they intend to effect too large and inhomogeneous groups of drivers. Identification of groups representing specific attitudes associated with specific risk behaviour more than others can help develop more adjusted and effective traffic safety interventions. The key determinants of risk behaviour and accident involvement should be identified and modified, and studied more closely to influence the specific groups.

The results show that dispositional concepts can yield useful information when appropriately applied. The focus should be on specific attitudes and related specific behaviours. However, many different factors influence behaviour in traffic. It might be optimistic to indicate that only attitudes as such can predict certain behaviours. In survey studies outside variables always encroach upon a dependent variable, and results are sensitive to forces other than those in the explicit defined theoretical system. Distinguishing “cause” and “effect” is not straightforward. Research reviewed in this article indicates that attitudes should be regarded as part of a complex dynamic system rather than simple evaluative judgements. Attitudes are inherently social, closely tied in with communication with others.

Specific attitudes predict specific behaviour, but the most efficient measure to change a specific behaviour is not necessarily to implement measures to change the corresponding attitude directly. One reason for the lack of success in changing health destructive behaviour might be that the measures have been too specifically related to certain beliefs and attitudes. Safe driving may be associated with other health protective behaviours. A complementary strategy for changing people’s choices and actions in a less destructive direction may therefore be to influence other types of behaviour as well as attitudes assumed to exert a direct influence on traffic behaviour.

The attitude-behaviour relationship has been the topic of considerable debate, and this paper has only touched upon some of the arguments. A basic understanding of the nature of attitudes and how it relates to behaviour seem vital, but the role of level of specificity, belief accessibility, frequency of past behaviour and moderating variables should also be considered in the process of developing effective intervention campaigns.

The second aim of this paper was to analyse the relationship between attitudes, risk behaviour, near misses, reactions from others and accident involvement. Risk behaviour had a direct effect on the reactions drivers receive from others in traffic, e.g. the police, other passengers. It is difficult to state whether reactions follow behaviour, or vice versa. Those who get involved relatively more often in risk behaviour might get more reactions from others. Alternatively, it may be that receiving many reactions also influence frequency of aggressive and risky driving. Risk behaviour had also a direct effect on both involvement in near misses and involvement in accidents. As expected, near misses and especially reactions from others influenced involvement in accidents directly. The association between reactions and accident were strong, which illustrate the importance of pinpointing target groups like those who have most positive attitudes towards rule violations and speeding, practice these attitudes and have received many reactions.

The majority of studies have used records of accidents as criteria for traffic safety measures. Comprehensive models of individual differences should be recorded on specific measures and include the behavioural level, not only outcomes. Mechanisms behind different types of accidents can be different, and both accident mass and related behaviour should be disaggregated (Summala, 1996). Accidents are rare events, and it is difficult to obtain valid information about occurrence and preceding behaviour. A strict experimental design and behaviour only measured by number of accidents, influence probability of making a type 2 error (deciding in favour of a 0 hypothesis that indicated that no correlation exist when this conclusion is actually false). Information trying to change attitudes to certain behaviours can have effects even if an immediate decline in number of accidents is not registered (Aarø & Rise, 1996). The information can also influence the foundation to change attitudes related to other favourable behaviours. This study indicates that self-reports may provide a sensitive and appropriate outcome for the study of the association between attitudes, risk behaviour and accident involvement. However, it is important to note that self-presentational issues can affect the results. Risk behaviour can be motivationally based, and certain people choose to present themselves as drivers who
commit driving violations. Others show a deliberate tendency to give favourable self-descriptions to make the best possible impression.

Environmental factors and situational aspects must also be considered when addressing these issues. These factors are more transient and temporary and can represent the stimuli to trigger reactions that stem from more temperamental or personality factors. Societal norms and pressures influence calculations and shape attitudes towards risk-taking and rule-breaking behaviour. Consequently, the study of rule violations and accident involvement must consider the inherent social context in which the actions take place.

**References**


Table 1. Means and S.D. for attitudes towards traffic safety.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Many traffic rules must be ignored to ensure traffic flow</td>
<td>3.40</td>
<td>1.03</td>
</tr>
<tr>
<td>2. It make sense to exceed speed limits to get ahead of Sunday drivers</td>
<td>3.13</td>
<td>1.07</td>
</tr>
<tr>
<td>3. Traffic rules must be respected regardless of road and weather</td>
<td>2.53</td>
<td>1.05</td>
</tr>
<tr>
<td>4. Speed limits are exceeded because they are too restrictive</td>
<td>3.46</td>
<td>1.10</td>
</tr>
<tr>
<td>5. It is acceptable to drive when traffic lights shifts from yellow to red</td>
<td>3.63</td>
<td>.92</td>
</tr>
<tr>
<td>6. It is unnecessary to respect a red traffic light when nobody is around</td>
<td>4.56</td>
<td>.72</td>
</tr>
<tr>
<td>7. Taking chances and breaking a few rules does not necessarily make bad drivers</td>
<td>3.43</td>
<td>1.05</td>
</tr>
<tr>
<td>8. It is acceptable to take chances when no other people are involved</td>
<td>4.13</td>
<td>.82</td>
</tr>
<tr>
<td>9. Traffic rules are often too complicated to be carried out in practice</td>
<td>3.90</td>
<td>.81</td>
</tr>
<tr>
<td>10. If you are a good driver it is acceptable to drive a little faster</td>
<td>3.85</td>
<td>.85</td>
</tr>
<tr>
<td>11. When road conditions are good and nobody is around driving in 100 mph is ok</td>
<td>3.30</td>
<td>1.08</td>
</tr>
<tr>
<td>12. Punishments for speeding should have been more restrictive</td>
<td>3.21</td>
<td>1.00</td>
</tr>
<tr>
<td>13. I will ride with someone who speeds if that’s the only way to get home at night</td>
<td>3.60</td>
<td>.92</td>
</tr>
<tr>
<td>14. I will ride with someone who speeds if others do</td>
<td>4.23</td>
<td>.74</td>
</tr>
<tr>
<td>15. I don’t want to risk my life and health by riding with an irresponsible driver</td>
<td>2.05</td>
<td>1.05</td>
</tr>
<tr>
<td>16. It is my responsibility to respond if my friends drives in an irresponsible manner</td>
<td>1.78</td>
<td>.69</td>
</tr>
<tr>
<td>17. I would never drive after drinking alcohol</td>
<td>1.55</td>
<td>.90</td>
</tr>
<tr>
<td>18. I would never ride with someone I knew have been drinking alcohol</td>
<td>1.47</td>
<td>.81</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), strongly agree to (5) strongly disagree.

Table 2. Means and S.D. for risk behaviour in traffic.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Break 50 mph speed limits with more than 10 mph</td>
<td>3.78</td>
<td>.87</td>
</tr>
<tr>
<td>2. Break 80-90 mph speed limits with more than 10 mph</td>
<td>2.99</td>
<td>1.02</td>
</tr>
<tr>
<td>3. Overtake the car in front even when it keeps appropriate speed</td>
<td>3.83</td>
<td>.95</td>
</tr>
<tr>
<td>4. Break traffic rules to secure more continuous driving</td>
<td>4.09</td>
<td>.68</td>
</tr>
<tr>
<td>5. Ignore traffic rules to proceed faster</td>
<td>3.53</td>
<td>1.03</td>
</tr>
<tr>
<td>6. Drive faster to catch up on an appointment</td>
<td>3.41</td>
<td>.92</td>
</tr>
<tr>
<td>7. Drive too close to the car in front to be able to stop if it was using the brake</td>
<td>2.11</td>
<td>.86</td>
</tr>
<tr>
<td>8. Are distracted because of things happening around you while driving</td>
<td>2.10</td>
<td>.81</td>
</tr>
<tr>
<td>9. Create dangerous situations because you are not attentive enough</td>
<td>2.44</td>
<td>.89</td>
</tr>
<tr>
<td>10. Drive without enough safety margins</td>
<td>3.85</td>
<td>1.12</td>
</tr>
<tr>
<td>11. Keep driving when you are tired and actually need a break</td>
<td>4.28</td>
<td>1.01</td>
</tr>
<tr>
<td>12. Drive short distances in a car without wearing a seat belt</td>
<td>4.83</td>
<td>.58</td>
</tr>
<tr>
<td>13. Drive long distances in a car without wearing a seat belt</td>
<td>2.57</td>
<td>.90</td>
</tr>
<tr>
<td>14. Reduce speed because the car behind you tries to pass</td>
<td>4.27</td>
<td>.71</td>
</tr>
<tr>
<td>15. Reduce speed when you see a sign indicating danger</td>
<td>3.71</td>
<td>.70</td>
</tr>
<tr>
<td>16. Reduce speed when conditions are bad even though the speed limits are higher</td>
<td>4.03</td>
<td>.54</td>
</tr>
<tr>
<td>17. Reduce speed to far below speed limit when the roads are slippery</td>
<td>3.45</td>
<td>.87</td>
</tr>
<tr>
<td>18. Drive after you have been drinking more than one glass of beer or wine</td>
<td>3.99</td>
<td>.80</td>
</tr>
<tr>
<td>19. Drive the morning after drinking, uncertain that the alcohol is out of your body</td>
<td>1.93</td>
<td>.74</td>
</tr>
<tr>
<td>20. Ride with a person you know have been drinking too much alcohol</td>
<td>1.89</td>
<td>.81</td>
</tr>
<tr>
<td>21. Reduce speed to 30 mph when signs show that you are in an area where children play.</td>
<td>3.64</td>
<td>.78</td>
</tr>
<tr>
<td>22. Reduce speed in areas where children plays even when no children can be seen</td>
<td>4.96</td>
<td>.24</td>
</tr>
<tr>
<td>23. Speak up and tell the driver when you think the driving is incautious</td>
<td>4.58</td>
<td>.64</td>
</tr>
<tr>
<td>24. Discuss traffic safety with others</td>
<td>4.94</td>
<td>.26</td>
</tr>
<tr>
<td>25. Drive below a speed limit of 30 mph</td>
<td>2.45</td>
<td>.95</td>
</tr>
<tr>
<td>26. Drive below a speed limit of 50 mph</td>
<td>2.52</td>
<td>.91</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), very often to (5) never.

Table 3. Dimensions of attitude towards traffic safety.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Factor loading</th>
<th>Cronbach’s α</th>
<th>Inter-item correlation</th>
<th>Loevinger’s H</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Attitude towards rule violations and speeding</td>
<td>.833</td>
<td>.59**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \lambda 1.1 )</td>
<td>.54</td>
<td>.59**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \lambda 1.2 )</td>
<td>.61</td>
<td>.63**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Means and S.D. for dimensions of attitudes towards traffic safety.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Attitude towards rule violations and speeding</td>
<td>2.41</td>
<td>.57</td>
</tr>
<tr>
<td>II Attitude towards others careless driving</td>
<td>2.00</td>
<td>.59</td>
</tr>
<tr>
<td>III Attitude towards drinking and driving</td>
<td>1.51</td>
<td>.79</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), strongly agree to (5) strongly disagree.

Table 5. Percentages, means and S.D. for “ideal” and “non-ideal” attitudes.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>“Ideal”</th>
<th>Neither “ideal” nor “non-ideal”</th>
<th>“Non-ideal”</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Attitude towards rule violations and speeding</td>
<td>28</td>
<td>61</td>
<td>11</td>
<td>1.83</td>
<td>.61</td>
</tr>
<tr>
<td>II Attitude towards others careless driving</td>
<td>59</td>
<td>38</td>
<td>3</td>
<td>1.44</td>
<td>.55</td>
</tr>
<tr>
<td>III Attitude towards drinking and driving</td>
<td>88</td>
<td>8</td>
<td>4</td>
<td>1.16</td>
<td>.46</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), strongly agree to (5) strongly disagree.

Table 6. Dimensions of risk behaviour in traffic.

<table>
<thead>
<tr>
<th>Factor loading</th>
<th>Cronbach’s α</th>
<th>Inter-item correlation</th>
<th>Loevinger’s H</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Violations of traffic rules/ speeding</td>
<td>.813</td>
<td>.73</td>
<td></td>
</tr>
<tr>
<td>λ1.1</td>
<td>.63</td>
<td>.68</td>
<td></td>
</tr>
<tr>
<td>λ1.2</td>
<td>.77</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>λ1.3</td>
<td>.70</td>
<td>.77</td>
<td></td>
</tr>
<tr>
<td>λ1.4</td>
<td>.48</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>λ1.5</td>
<td>.68</td>
<td>.71</td>
<td></td>
</tr>
<tr>
<td>λ1.6</td>
<td>.71</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>II Reckless driving/ funriding</td>
<td>.671</td>
<td>.66</td>
<td></td>
</tr>
<tr>
<td>λ2.7</td>
<td>.62</td>
<td>.68</td>
<td></td>
</tr>
<tr>
<td>λ2.8</td>
<td>.41</td>
<td>.62</td>
<td></td>
</tr>
<tr>
<td>λ2.9</td>
<td>.48</td>
<td>.63</td>
<td></td>
</tr>
<tr>
<td>λ2.10</td>
<td>.59</td>
<td>.70</td>
<td></td>
</tr>
<tr>
<td>λ2.11</td>
<td>.57</td>
<td>.67</td>
<td></td>
</tr>
<tr>
<td>III Not using seat belts</td>
<td>.677</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>λ3.12</td>
<td>.89</td>
<td>.95</td>
<td></td>
</tr>
<tr>
<td>λ3.13</td>
<td>.67</td>
<td>.82</td>
<td></td>
</tr>
<tr>
<td>IV Cautious and watchful driving</td>
<td>.665</td>
<td>.71</td>
<td></td>
</tr>
<tr>
<td>λ4.14</td>
<td>.38</td>
<td>.65</td>
<td></td>
</tr>
<tr>
<td>λ4.15</td>
<td>.55</td>
<td>.71</td>
<td></td>
</tr>
<tr>
<td>λ4.16</td>
<td>.70</td>
<td>.73</td>
<td></td>
</tr>
</tbody>
</table>
Table 7. Intercorrelations between the dimensions of risk behaviour (λ-values).

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Violations of traffic rules/ speeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II Reckless driving/ funriding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III Not using seat belts</td>
<td>.63</td>
<td>.43</td>
<td>.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV Cautious and watchful driving</td>
<td>-.41</td>
<td>-.32</td>
<td>-.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V Drinking and driving</td>
<td>.42</td>
<td>.40</td>
<td>.31</td>
<td>-.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI Attentiveness of children in traffic</td>
<td>-.19</td>
<td>-.25</td>
<td>-.05</td>
<td>.47</td>
<td>-.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII Discussing traffic safety with others</td>
<td>-.32</td>
<td>-.28</td>
<td>-.14</td>
<td>.43</td>
<td>-.21</td>
<td>.27</td>
<td></td>
</tr>
<tr>
<td>VIII Driving below speed limits</td>
<td>-.17</td>
<td>-.09</td>
<td>-.09</td>
<td>.35</td>
<td>-.11</td>
<td>.31</td>
<td>.17</td>
</tr>
</tbody>
</table>

Table 8. Means and S.D. for dimensions of risk behaviour in traffic.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Violations of traffic rules and speeding</td>
<td>2.31</td>
<td>.68</td>
</tr>
<tr>
<td>II Reckless driving/ funriding</td>
<td>2.11</td>
<td>.46</td>
</tr>
<tr>
<td>III Not using seat belts</td>
<td>1.45</td>
<td>.72</td>
</tr>
<tr>
<td>IV Cautious and watchful driving</td>
<td>2.21</td>
<td>.59</td>
</tr>
<tr>
<td>V Drinking and driving</td>
<td>1.18</td>
<td>.29</td>
</tr>
<tr>
<td>VI Attentiveness of children in traffic</td>
<td>2.11</td>
<td>.77</td>
</tr>
<tr>
<td>VII Discussing traffic safety with others</td>
<td>2.48</td>
<td>.79</td>
</tr>
<tr>
<td>VIII Driving below speed limits</td>
<td>3.47</td>
<td>.91</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), very often to (5) never.

Table 9. Percentages, means and S.D. for “ideal” and “non-ideal” behaviour.

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>“Ideal”</th>
<th>Neither “ideal” or “non-ideal”</th>
<th>“Non-ideal”</th>
<th>Mean</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Violations of traffic rules and speeding</td>
<td>38</td>
<td>50</td>
<td>12</td>
<td>1.74</td>
<td>.66</td>
</tr>
<tr>
<td>II Reckless driving/ funriding</td>
<td>49</td>
<td>48</td>
<td>3</td>
<td>1.53</td>
<td>.55</td>
</tr>
<tr>
<td>III Not using seat belts</td>
<td>88</td>
<td>8</td>
<td>4</td>
<td>1.15</td>
<td>.45</td>
</tr>
<tr>
<td>IV Cautious and watchful driving</td>
<td>45</td>
<td>48</td>
<td>7</td>
<td>1.61</td>
<td>.60</td>
</tr>
<tr>
<td>V Drinking and driving</td>
<td>99</td>
<td>1</td>
<td>0</td>
<td>1.01</td>
<td>.11</td>
</tr>
<tr>
<td>VI Attentiveness of children in traffic</td>
<td>64</td>
<td>29</td>
<td>7</td>
<td>1.43</td>
<td>.62</td>
</tr>
<tr>
<td>VII Discussing traffic safety with others</td>
<td>39</td>
<td>46</td>
<td>15</td>
<td>1.76</td>
<td>.70</td>
</tr>
<tr>
<td>VIII Driving below speed limits</td>
<td>11</td>
<td>30</td>
<td>59</td>
<td>2.48</td>
<td>.69</td>
</tr>
</tbody>
</table>

Ratings given on a 5-point scale from (1), very often to (5) never.
Root Mean Square Residual (RMSEA) = .10, \( \chi^2 = 4431 \), d.f. = 55, Goodness of Fit Index (GFI) = .92, Adjusted GFI = .88

**Figure 1. Attitudinal predictors of risk behaviour.**

Root Mean Square Residual (RMSEA) = .067, \( \chi^2 = 7526 \), d.f. = 190, Goodness of Fit Index (GFI) = .93, Adjusted GFI = .90

**Figure 2. Effects of attitudes, behaviour, reactions from others and near-accidents on accident involvement.**
ATTITUDES TOWARDS TRAFFIC SAFETY, RISK PERCEPTION AND BEHAVIOUR AMONG YOUNG NORWEGIAN DRIVERS AND THEIR PASSENGERS

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Abstract

During the last few years the frequency of fatal injuries caused by traffic accidents has increased in Norway and this is a threat to public health. Young drivers and their passengers are high-risk groups and accidents amongst adolescents reduce the years of living more than most other threats to human health. Therefore, the Norwegian Authorities of Public Roads prioritize to find measures aimed at reducing the number of health injuries caused by adolescent risk taking in traffic. The present paper shows some results from a study aimed at evaluating the effects of several measures implemented to promote adolescent safe driving behavior in two Norwegian counties. A total of about 4376 respondents have responded to a self-completion questionnaire, including adolescents in the two counties as well as respondents from other counties not taking part in the intervention program. The response rate was 93 percent. There was a significant change in self-report behavior, attitudes towards traffic safety and risk perception when the group of respondents replying to the questionnaire before exposed to the measures was compared to those who did so after. The number of accidents is also reduced to a greater extent in the two participating counties compared to other Norwegian counties. Multivariate analyses showed significant associations between risk perception, risk-taking attitudes and driving behavior. Model tests showed that assessments of the probability of traffic accidents and concern were insignificant predictors for self-report risk behaviour. Worry and emotional reactions related to traffic hazards significantly predicted behaviour. Sensation seeking, normlessness, and indifference with regard to traffic safety affected emotion-based risk perception.

Introduction

Young drivers are more frequently involved in accidents caused by inappropriate speed and loss of control of the vehicle compared to other age groups of drivers (Jonah, 1986; Michiels and Schneider, 1984; Tränkle et al., 1990). Their accidents also more often take place in curves and are caused by speeding. These types of accidents are also associated with open roads and rural traffic environments. In Norway a campaign to promote safe driving behaviour, has been carried out among adolescents in two counties since 1998. The campaign focused especially on speeding accidents. The main elements were two multimedia productions, a training program about traffic safety to be applied by high schools, and extensive police surveillance. In addition, posters, movie commercials as well as competitions on traffic safety knowledge were part of the campaign. The posters aimed at reaching sensation seekers, “normless” adolescents and those who were indifferent with regard to traffic safety. These groups were hypothesised to be especially vulnerable to traffic accidents and therefore important to reach. Campaign teams also visited the high schools in the two
counties to talk personally to every adolescent about traffic hazards and traffic safety. The teams consisted of persons from the Authorities of Public Roads, the police and persons who had been victims of serious traffic accidents. *The first aim of the present paper is to examine some of the effects of the campaign.*

The majority of traffic campaigns are aimed at influencing attitudes towards traffic safety. However, many evaluation studies have failed to document effects on traffic safety. The reasons are several. According to Wilde (1993) and Aarø and Rise (1996) the measurement instruments applied for evaluation of effects have been inappropriate in many of the studies. In addition, accident is often the only criterion variable and this is not always an ideal criterion. A third cause for the lack of success can be that the campaigns have aimed at influencing safety attitudes in general, and did not to a proper extent focus on perception of risk.

Deery (1999) concluded that young novice drivers are characterised by perceiving relatively low levels of risk in specific driving situations compared to other groups of drivers. According to Brown and Groeger (1988) the overrepresentation of young novice drivers in specific types of accidents, e.g. those caused by inappropriate speeding, is that they underestimate the probability of specific risks caused by these traffic situations. The perceptions include potential hazards in the environment as well as self-assessed driving ability. Young drivers perceive hazards in traffic less holistically (Milech, Glencross and Hartley, 1989; Deery, 1999), and concentrate on the danger rather on the difficulty involved in carrying out particular manoeuvres (Groeger and Chapman, 1996). They also detect hazards more slowly, and fail to discover hazards more often (McKenna and Crick, 1997). Glik, Kronenfeld, Jackson and Zhang (1999) found that younger men did not perceive themselves at greater risk of traffic accidents compared to other groups. Accordingly, Gregersen (1996) found that young drivers tended to overestimate their own driver skills. Sivak, Soler, Traenkle and Sagnhol (1989) analysed risk perception related to 23 slide-projected traffic scenes among a total of 400 drivers. 18-24 years old drivers reported lower risk than did middle-aged. In general, the majority of surveys show that young drivers underestimate hazards in traffic. In many studies judgement bias is hypothesised to be the core causal factor for accidents.

In line with other risky activities traffic accident is linked to negative consequences, i.e. damages, injuries, sickness, losses and human suffering. Risky activities or hazard may therefore also be associated with insecurity, worry, and anxiety. However, affective reactions have rarely been measured in studies on perception of traffic risks. Especially, there is a lack of research analysing the relative importance of affect and cognition in risk judgements and risk behaviour.

Multicomponent models of attitudes suggest that cognitive and affective responses are separable, yet related, aspects of attitudes (e.g Eagly and Chaiken, 1993; Zanna and Rempel, 1988, see also Haddock and Zanna, 1999). Cognitive-based and emotion-based elements of attitudes related differently to past experience and behaviour (Brecker and Wiggins, 1989; Millar and Tesser, 1986). Affective reactions have also been hypothesised to be primary to cognition (Zajonc; 1980; Murphy and Zajonc, 1993; Rundmo and Sjöberg, 1998; Rundmo, 2000). If affect and cognition can be distinguished, the reasons for affect being primary to cognition may be that evaluative judgements related to cognition are more “complex” compared to an overall assessment of one’s feelings. Verplanken, Hofste and Janssen (1998) showed in an experiment that the response time was shorter when respondents were instructed
to report their feelings towards an object compared to their beliefs. The explanation set forward was that emotion-based responses are primary because they are more “accessible” compared to cognition-based responses. According to Mehrabian and Russel (1974) affect is crucial for how people would behave in a setting. Physical features of the environment as well as social aspects of a setting are relevant for emotions as well as behaviour (Orford, 1992). The hypothesis of the present study is that emotion-based risk perception influences risk behaviour in traffic and cognition-based perception is not significantly associated with behaviour. Affectivity may be critical for the capability of adjusting to the traffic setting and of avoiding traffic hazards. Therefore, emotions are basic to cognition.

In addition to the characteristics of the setting, people’s experience of the setting is partly an individual matter (Mehrabian and Russel, 1974). Consequently, personality factors may be associated with affective reactions to the situation or the setting, as well as with risk behaviour. Deery and Fildes (1999) found that high-risk young novice drivers were characterised by high levels of sensation seeking, aggression, driving to reduce tension, and hostility. In a study aimed at finding measures to reduce rail-automobile accidents, Witte and Donohue (2000) showed that sensation-seeking tendencies caused the driver to experience greater frustration and exhibit greater judgement distortions around rail crossings, which in turn resulted in risk behaviour. A study of male taxi drivers also showed that high-risk personality and sensation seeking were associated with high speeding and traffic rule violations (Burns and Wilde, 1995). Several other studies have also shown an association between sensation seeking and mood as well as emotions (Carton, Jouvent, Bungener and Widloecher, 1992; Lawton, Powell, Rajagopal and Dean, 1992; Teichman, Baarnea, and Rahav, 1989). If emotions are important for traffic behaviour and individual factors affect how drivers perceive traffic settings, we would expect personality variables to be significantly associated with affectivity. Accordingly, the second aim of this paper is to examine the association between risk perception and traffic behaviour and examine the relative effects of cognitive-based and emotion-based risk perception in behaviour as well as the interaction between risk perception, behaviour and personality.

Methods

Sample

A survey was carried out among adolescents aged 18-24 years old in two Norwegian counties. The questionnaire was filled in during school visits in the classroom and collected immediately after completion (n=4376). Of these, 306 questionnaires were excluded from further analysis because they either were not filled in, unsatisfactorily answered or because the answers were not valid. The response rate was 93 per cent. There were 1769 male and 2232 female respondents and 1795 of the respondents had a driving licence.

Questionnaire

The questionnaire contained a total of nine indicators of risk perception (see Table 1). The indicators were intended to measure different aspects of perceived risk, including probability assessments related to health injuries caused by traffic accidents as well as worry and concern, i.e. affectivity when considering on traffic related risks. The assessments included the
probability for the respondent himself or herself as well as for an adolescent in general. The same distinction was measured for worry and concern. The respondents were also asked to assess how often they thought about traffic related hazards and were concerned about them. A seven-point bipolar evaluation scale was applied for measuring all types of risk perception. In addition, the questionnaire contained eight indicators of affective reactions related to traffic risks. A seven-point semantic differential was applied to measure affect. The respondents were asked to assess to which extent they were worried, elated or depressed, in a good or bad mood, calm or upset, relaxed or anxious, balanced or irritated, happy or sad, and concerned or non-concerned when thinking about traffic related risks and hazards. A seven-point bipolar scale was applied on all these items. The following personality traits were measured: Sensation seeking (Costa and McCrae, 1994), normlessness (Kohn and Schooler, 1983), and indifference and bluntness related to traffic safety (Rundmo and Ulleberg, 2000). Fifteen indicators measured self-report risk behaviour (Rundmo, 1996, 1998). The respondents were also asked for their age, gender, whether or not they had a driving licence and also about their experience as a driver.

**Statistical Analysis**

Principal component analysis with varimax rotation and iteration was used to identify dimensions of perceived risk, affect when thinking on traffic related risks, and concern as well as risk behaviour. Cronbach’s $\alpha$ checked internal consistency. In addition to the $\alpha$, Mokken scale analysis (Mokken, 1971) for polytomous items was applied to test the reliability of the items identified through the principal component analyses (Molenaar, Debets, Sijtsma and Hemker, 1994). The scalability of the total scale is defined by Loewinger’s H coefficient, which is calculated $1 - F/E$. The indicators belong to the same underlying dimension if all $H_{ij} > 0$. Another requirement is that for all the item coefficients of scalability, $H_i$ is larger than the constant $c > .30$. $H < 0.30$ indicates that the indicators do not form a scale. When the $H$-value is around 0.30 the indicators form a weak scale. An average scale has an $H$ - value around 0.40 to 0.50 and a value > 0.50 indicates a strong scale.

Structural Equation Modelling (SEM) was applied to examine associations between risk perception and risk behaviour in traffic as well as in the analysis of indirect and moderating effects on risk behaviour of the personality variables. Unweighted $z$-scores were applied in all analyses. The interaction effects were entered as directly observed predictors and the latent variable was measured by several directly observed predictors, i.e. a MIMIC (Multiple Indicators and Multiple Causes) - model. This model consisted of one latent endogenous variable and several directly measured predictor variables. This model was selected because the aim was to determine the effect of each predictor separately, i.e. to analyse the relative association with risk behaviour of cognitive-based and emotion-based risk assessments. In addition, the same type of model was applied for analysing interactions or mediating effects of the personality variables (sensation seeking, normlessness and indifference). To avoid the problem of multicollinearity in the analysis of mediator effects the procedure described by Dunlap and Kemery (1987) was used. A SEM-model with latent variables on personality, risk perception and risk behaviour was used to examine indirect effects of personality on risk behaviour. Associations between the MIMIC-models as well as the confirmatory factor analyses and our data were examined by means of Root Means Square of Approximation (RMSEA), the $\chi^2$ – test as well as the General Fit Index (GFI) and the
Adjusted GFI (AGFI). Due to the fact that there are several problems with applying the $\chi^2$-test as a fit measure, (see e.g. Hu and Bentler, 1995), we did not give too much weight to deviations between the model and the data. The size of the sample was large and the models were quite complex. The other fit indices (GFI and AGFI) were satisfactory, $> 0.900$ and RMSEA $< 0.07$.

Results

Dimensions of Perceived Risk

Table 1 shows that the risk perception indicators were separated into three different dimensions (see also Rundmo and Ulleberg, 2000a-c, Ulleberg and Rundmo, 2000). The first measured affect related to traffic related risk, i.e. the extent to which the respondent felt safe or unsafe, as well as worried and concerned, $\alpha = 0.89$, Loevinger’s $H = 0.71$. The second dimension consisted of the cognitive aspects of risk perception, which was the probability assessments, $\alpha = 0.67$, Loevinger’s $H = 0.54$, and the third was concern, which is how often the respondent was thinking about traffic related hazards, $\alpha = 0.81$, Loevinger $H = 0.70$. In addition, item-analysis was carried out by correlating the corrected sum score for a dimension with each of the single indicators of the dimension. The corrected total score was the score for all items of a dimension minus the single item which the sum score was correlated with. An indicator measures the same as the other indicators when the correlation coefficient is above 0.30. Due to the fact that the reliability was satisfactory for all the three dimensions there was no reason for conducting inter-item analysis. Thereafter, a principal component analysis of the emotion-indicators was carried out. The exploratory analysis showed that the indicators fell into one dimension (Table 2). The item-analysis also showed that the reliability was satisfactory when the last indicator was removed, $\alpha = 0.89$, Loevinger’s $H = 0.64$.

Table 1: Dimensions of risk perception

| Dimension 1: Emotion-based risk perception: Worry and insecurity |
|-----------------------------|-----------------------------|-----------------------------|
| Feeling unsafe that you yourself could be injured in a traffic accident | .87 | .16 | .13 |
| Worried about yourself being injured in a traffic accident | .87 | .14 | .14 |
| Feeling unsafe that an adolescent in general could be injured in a traffic accident | .83 | .20 | .15 |
| Worried that an adolescent in general could be injured in a traffic accident | .79 | .21 | .22 |

| Dimension 2: Cognition-based risk perception: Probability assessments |
|-----------------------------|-----------------------------|-----------------------------|
| How probable do you think it is in general for an adolescent to be injured in a traffic accident? | .21 | .84 | - |
| How probable do you think it is for yourself to be injured in a traffic accident? | .19 | .84 | - |

| Dimension 3: Concern |
|-----------------------------|-----------------------------|
| How concerned are you about traffic risks and what do you think about the risks for an adolescent in general? | .17 | - | .90 |
| How concerned are you about traffic risks and the possibility that you yourself could be the victim of an accident | .20 | - | .89 |
Table 2. Dimensions of emotion-based risk perception: Emotional reactions to traffic risk

<table>
<thead>
<tr>
<th>Dimension 1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Relaxed – anxious</td>
<td>.87</td>
</tr>
<tr>
<td>Calm – upset</td>
<td>.86</td>
</tr>
<tr>
<td>In good mood – in bad mood</td>
<td>.81</td>
</tr>
<tr>
<td>Happy – sad</td>
<td>.81</td>
</tr>
<tr>
<td>Balanced – irritated</td>
<td>.76</td>
</tr>
<tr>
<td>Elated – depressed</td>
<td>.72</td>
</tr>
<tr>
<td>Very worried – not at all worried</td>
<td>.65</td>
</tr>
<tr>
<td>Concerned – non-concerned</td>
<td>.42</td>
</tr>
</tbody>
</table>

Eigenvalue 4.52  
56.4% explained variance

Identical analyses to those carried out for testing the reliability of risk perception were used on risk behaviour. The following three dimensions appeared. The first was entitled unsafe driving and social pressure, which contained indicators of behaviour motivated by expectations and pressure from significant other persons, $\alpha = 0.91$, Loevinger’s H = 0.71. The second was speeding, i.e. breaking the speed limits, $\alpha = 0.87$, Loevinger’s H = 0.62 and the third rule violations, $\alpha = 0.73$, Loevinger’s H = 0.48. All the test items were also computed into one dimension of risk behaviour. The reliability of this index was also found to be satisfactory, $\alpha = 0.91$, Loevinger’s H = 0.48 (see Rundmo and Ulleberg, 2000b-c; Ulleberg and Rundmo, 2000 for further details).

Risk Perception before and after the Campaign

Respondents who answered the questionnaire before the campaign started were compared to those who did so after school visits and after personal exposure to the measures of the campaign. The recipients of the campaign judged traffic accident risk to be larger after being exposed to the measures of the campaign compared to before it started. As shown by d-values (effect sizes) the difference was greatest for the probability assessments. To experience traffic accidents was judged to be more probable after the campaign compared to before it started. The respondents in the post-sample were also more worried and unsafe compared to the respondents who answered the questionnaire before the campaign started. In addition, they were also significantly more concerned after the campaign, although the effect sizes were relatively small for worry and concern. Of the eight indicators making up the four dimensions the difference was significant on seven. A sign-test also clearly indicated that there was a difference in risk perception in general in the two samples, $p < 0.05$. For seven of the eight indicators of affective reactions the difference between those who answered the questionnaire before the campaign started was also significant compared to those who did so after. A sign test indicated that the respondents in the post-sample were more affective compared to the pre-sample, $p < 0.05$. However, the d-values the differences were relatively small. Chi-square tests showed that there were no significant differences between the pre- and post samples with regard to the number of respondents who had experienced a traffic accident as a driver, $\chi^2 = 3.11$, $p = 0.211$, who had experienced a traffic accident themselves as a passenger, $\chi^2 = 0.436$, $p = 0.436$, who had experienced a traffic accident as a pedestrian, $\chi^2 = 2.07$, $p = 0.354$. Neither were there sex or age differences between the respondents of the samples, $p > 0.05$. 
The results showed that there were significant differences in risk perception and affective reactions when respondents who answered the questionnaire before the campaign started were compared to those who did so after it had started and later exposed to the measures. However, the tests which were used were not aimed at determining whether it was the school visits or the fact that the campaign was started which originated the difference. A one-way analysis of variance was carried out to compare the group of respondents in the experimental group who answered the questionnaire before the campaign started with those who answered after the campaign, and immediately after the school visit. A total of 1846 respondents in the experimental group replied to the questionnaire before the campaign team visited their school, but after the start of the campaign. Table 3 shows the F-values and also the results of the Bonferroni’s Post Hoc correction.

Respondents who answered the questionnaire before the campaign differed from those who did so after, although before their school had been visited, $p < .05$. The evaluation differed more significantly when the pre-sample was compared to the respondents who replied immediately after the school visit, i.e. after being exposed to the measures of the campaign for the first time. The results indicate that it was primarily the combination of measures which affected perceived risk.

<table>
<thead>
<tr>
<th>Table 3. Pre- and post-sample comparison – risk perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk perception F - value</td>
</tr>
<tr>
<td>Dimension 1: Probability assessments</td>
</tr>
<tr>
<td>Dimension 2: Concern</td>
</tr>
<tr>
<td>Dimension 3: Worry</td>
</tr>
<tr>
<td>Dimension 4: Emotional reactions</td>
</tr>
<tr>
<td>Emotional reactions – single indicators:</td>
</tr>
<tr>
<td>Calm – upset</td>
</tr>
<tr>
<td>In good mood – in bad mood</td>
</tr>
<tr>
<td>Happy – sad</td>
</tr>
<tr>
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<td>Elated – depressed</td>
</tr>
<tr>
<td>Very worried – not at all worried</td>
</tr>
<tr>
<td>Concerned – non-concerned</td>
</tr>
</tbody>
</table>

* = $p < .05$, ** = $p < .01$, *** = $p < .001$, NS = non-significant

Self-Report Risk Behaviour and Accidents before and after the Campaign

Respondents reported less risk behaviour after the campaign compared to before on all the three dimensions. Speeding was significantly reduced, $t = -8.23$, $p < 0.001$, $z = -7.17$, $p < 0.001$, $d = 0.81$. There were also small, however not significant reductions in unsafe driving caused by social pressure, $d = 0.26$, and rule violations, $d = 0.13$. As shown in the methodological section of the present paper, the risk behaviour scale was also reliable when all the items were computed into one dimension. On average, traffic behaviour was reported
to be less risky after the campaign compared to before, $t = -2.22$, $p = 0.5$, $z = -2.35$, $p < 0.05$, $d = 0.35$.

ARIMA regression analysis showed a 13 per cent reduction in accidents caused by speeding and a seven per cent decrease in all accidents in the two counties where the campaign was carried out when controlled for accidents in all other Norwegian counties and taking seasonal variations in the period 1990-1999 into account. However, the reduction in accident frequency was not significant, neither did we expect it to be so shortly after the campaign started (see Rundmo and Ulleberg, 2000,a-c and Ulleberg and Rundmo, 2000 for further detail).

**Association between Risk Perception and Risk Behaviour**

Risk perception is interesting because it is hypothesised to influence behaviour. Consequently, we expected to find a significant association between risk perception and self-report behaviour. A MIMIC (Multiple indicators and multiple causes) -model consisting of one latent endogenous variable (risk behaviour), and four directly measured exogenous variables, which were perceived risk. The hypothesis to be tested had the following structural equation: $\eta_1 = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \zeta$. The measurement model equations for the measurement model (y-variables) were: $y_1 = \lambda_{11} (y) \eta_1 + \epsilon_1$, $y_2 = \lambda_{21} (y) \eta_1 + \epsilon_2$, $y_3 = \lambda_{31} (y) \eta_1 + \epsilon_3$. The analysis was restricted to respondents who had a driving licence.

Rational” aspects of perceived risk, i.e. the respondents’ subjective assessments of experiencing a traffic accident and how “concerned” they were with the risks, were totally insignificant predictors of risk behaviour in traffic, $\gamma$-values of -0.008 and -0.003 respectively. However, worry as well as the general measure of emotional reactions related to traffic hazards were significantly associated with risk behaviour ($\gamma = -0.056$ for worry and $\gamma = -0.304$ for affectivity). The more risky traffic hazards were judged to be, the more safe was the respondents’ own driving behaviour. These two variables alone explained 12 per cent of the variance of risk behaviour, $e = 0.88$. The model fit was also satisfactory despite the fact that the $\chi^2$-test showed that the data deviated moderately from the model, $\chi^2 = 196,92$, d.f. = 8, $p < .05$, GFI = 0.986, AGFI = .952. The model deviated somewhat from the data, although not unacceptably. The Goodness of Fit index (GFI) and the Adjusted GFI (AGFI) were both satisfactory, > 0.900.

Thus, probability judgements and concern about traffic risks seem not to be important for risk behaviour in traffic, while affect seems to be important. The results of a SEM-analysis where the personality factors the campaign was especially directed to reach were entered into the model presented above. The hypotheses to be tested had the structural equations $\eta_1 = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \zeta$, $\eta_2 = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \zeta$. The measurement model equations for the measurement model (y-variables) were: $x_1 = \lambda_{11} (x) \xi_1 + \delta_1$, $x_2 = \lambda_{21} (x) \xi_1 + \delta_2$, $x_3 = \lambda_{31} (x) \xi_1 + \delta_3$, $y_1 = \lambda_{11} (y) \eta_1 + \epsilon_1$, $y_2 = \lambda_{21} (y) \eta_1 + \epsilon_2$, $y_3 = \lambda_{32} (y) \eta_2 + \epsilon_3$, $y_4 = \lambda_{42} (y) \eta_2 + \epsilon_3$, $y_5 = \lambda_{52} (y) \eta_2 + \epsilon_3$.

The model explains 42 per cent of the variance in risk behaviour, $e_2 = 0.58$. Affectivity was a strong predictor of risk behaviour, $\beta_{21} = -0.65$. The personality factors were also strongly associated with affectivity, $\gamma_{11} = -0.87, e_1 = 0.24$. The model fit was judged to be satisfactory, Goodness of Fit Index (GFI) = 0.947, Adjusted GFI 0.895, $\chi^2 = 872,78$, d.f. = 18, $p < 0.05$. The indicator sensation seeking failed to load on the latent exogenous variable, $\lambda_{(x)11}=0.38$. A re-analysis was conducted removing this predictor. The model fit improved
somewhat, GFI = 0.959, AGFI 0.905, $\chi^2 = 575.71$, d.f. = 12, $p < 0.05$. However, this reduced the power of the model, which explained only 38 per cent of the variance, $e_2 = 0.62$, indicating that sensation seeking was an important predictor which should not be excluded.

Above it was shown that personality exerted an indirect effect on risk behaviour in traffic. The possibility that personality may have a moderating effect on the relation between risk perception and behaviour was also examined. The hypothesis to be tested had the following structural equation: $\eta_1 = \gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_3 + \gamma_4 x_4 + \gamma_5 x_5 + \gamma_6 x_6 + \gamma_7 x_7 + \gamma_8 x_8 + \zeta$. The measurement model equations for the measurement model ($y$-variables) were: $y_1 = \lambda_{11} \eta_1 + \varepsilon_1$, $y_2 = \lambda_{21} \eta_1 + \varepsilon_2$, $y_3 = \lambda_{31} \eta_1 + \varepsilon_3$.

The $\gamma$-values for the combinations were small, all the $\gamma$-values < 0.10, showing that personality was not a moderator of the associations between perceived risk and risk behaviour. However, the results indicated that personality exerted a significant indirect effect on risk behaviour, via the strong association it had with perceived risk. An additional analysis combining worry and affect as well as the personality variables did not increase the explained variance significantly. For analysis 1 $e_1 = 82$, $R^2 = 0.18$, $\chi^2 = 125.52$, d.f. = 18, $p < .01$, GFI = 995, AGFI = 987. Due to the fact that there were low correlations between probability assessment and risk behaviour, no additional analysis for determining the interaction between the personality variables concern, risk perception and behaviour was conducted.

**Conclusion**

The results of the present study showed that a traffic safety campaign carried out among adolescents in two Norwegian counties significantly seemed to have changed risk perception related to speeding and other traffic hazards. The change was significant on all dimensions and also on every single indicator of risk perception. The respondents of the post-sample also reported less risk behaviour in traffic and the number of speeding accidents was reduced with 13 per cent. Perceived risk was not changed among adolescents in two other countries where the campaign had not taken place. Neither were there any changes in self-report risk behaviour. There were no significant differences between samples with regard to sex, age, percentage who had a driving licence, driver experience or accident records. Thus, there is reason to believe that it was the campaign that caused the change in risk perception in the experimental group. The campaign is going to last until year 2003. The purpose of the first evaluation reported here was to see whether or not there were elements of the campaign which should be corrected for the remaining period in order to improve its effectiveness.

Risk perception is primarily interesting because it may affect behaviour. The model tests presented showed that probability assessments and concern, i.e. “rational” aspects of risk perception, were insignificant predictors for self-report risk behaviour. Worry and emotional reactions significantly predicted behaviour. This is contrary to the majority of studies which seem to be based on the assumption that traffic accidents among young drivers are caused by “misperception” of dangers and traffic hazards. However, these results do not imply that misjudgements and probability assessments are insignificant causal factors in traffic accidents. Subjective assessments related to specific risk sources have to be distinguished from general risk perception, i.e. how the probability for traffic in general is assessed and how worried and “emotional” the respondent in general “feels” when thinking about all the risks. Our questionnaire measured perceived risk in general, not related to specific hazards and traffic situations.
The campaign was aimed at reaching high-risk groups of sensation seekers, "normless" adolescents and those who were indifferent to traffic safety. Based on previous empirical studies it was hypothesised that these groups were vulnerable to traffic accidents. Two hypotheses were tested. The first one was that these personality factors had an indirect effect on risk behaviour in traffic and the second that personality moderated the association between risk perception and behaviour. We found rather small and insignificant moderating effects. However, personality had a strong indirect effect on risk behaviour and was an important predictor of affect.

References


THE INFLUENCE OF SIGHT DISTANCE FOR THE SPEED OF VEHICLES AND ROAD SAFETY
- Inquiry and Comparison in Different European Countries -

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Importance of Sight Distances in Road Design

The road safety has, due to many road casualties, an important part in modern road design. Numerous examinations in many countries have proofed the immense importance of sight distance for the road safety. This results out of the relationship man – vehicle – surrounding environment. In the roadside environment the existing sight distance has an important influence on the choice of speed for the driver of the vehicle. This could be described as a standard rule. An examination on the influence of sight distance and other parameters for the road safety has been made by Krebs/Klöckner (1977) and Leutzbach/Zoellmer (1989) and is considered in the German road design guidelines (Figure 1). In 1968 Hiersche summerized the influence of sight distances. According to these 44 % of all accidents are due to the cause of “obstruction of visibility”, which is the largest group in all road accidents.

With the increase of sight distance the number of accidents decline. Hiersche also shows, that the number of obstructions of sight have an important influence on the accident occurence. The accident risk rises with the increase of obstructions of visibility and than declines again.
This is due to the fact, that by continuous obstruction of visibility the average speed is lowered. Resulting to this the accident risk sinks. Those roads, however, which have obstruction of visibility over a short distance, but are otherwise designed continuously bear a higher accident risk.
**Stopping Sight Distance**

Stopping sight distance is needed for a driver, who must be able to see ahead in order to identify hazards to bring his vehicle safely to a stop, when necessary. The required stopping sight distance is needed by a driver to stop the vehicle before reaching an unexpected obstacle on the road when riding at the 85th-percentile speed $V_{85}$. The stopping sight distance is the sum of two components: reaction distance and braking distance.

**Overtaking Sight Distance**

Overtaking (passing) sight distance is needed on two-lane roads for safely overtaking. The required overtaking sight distance is necessary for the safe performance of an overtaking maneuver. The models for this maneuver are different in countries. Figure 2 shows the model for the overtaking sight distance in the German Guidelines RAS-L, 1995. For safety reasons the overtaking sight distance depend also on the speed $V_{85}$.

![Figure 2: The Model of Overtaking Sight Distance in the German Guidelines RAS-L, 1995](image)
Influence of Sight Distances on the Driver Behaviour

The speed, which the driver of a vehicle chooses, is influenced by many factors. These results aside from the subjective ones mostly out of the roadside environment and the road design. The speed which occurs on a road section is related to the structural extension of a road, the topography, the design of the road, the density of traffic and the traffic composition. The following data are describing the speed of vehicles often used in the road design process:

\[ V_{50} \]: the speed \( V_{50} \) corresponds to the speed below which 50\% of passenger cars operate under free-flow conditions (median).

\[ V_{85} \]: the speed \( V_{85} \) corresponds to the speed below which 85\% of passenger cars operate under free-flow conditions (approximately the sum of the mean value and the standard deviation of a normal distribution of speed).

German as well as British design rules refer to the speed which can be expected. But guidelines in Germany only name as decisive the Bendiness \( k \) [gon/km] and the width of the road \( B \) [m] for roads in category A. These data origin from an examination made by Köppel/Bock (1970) and are to be used under the premise that the road is clean and wet and that a vehicle can drive without being obstructed by other cars (free-flow conditions). The influence of obstruction of visibility is integrated into the bendiness and the width of the road also the obstruction of visibility and the design of the road’s surroundings.

The British guidelines consider beside these influences also the existing sight distance and the design of the roadside environment (see Figure 3).

The Alignment Constraint \( A_c \) is described by the visibility and bendiness. The way to acquire the data for the sight distances will be described later. The Layout Constraint \( L_c \) is influenced by the roadside environment. From the traverse profile, the width of the marginal strip and the number of connections and junctions per road kilometre result the Layout Constraint \( L_c \). Numerous examinations are the basis for the British guidelines.
Measurement of Sight Distance and Driver Behaviour

Speed and sight distance play an important role in road safety. Due to the differences between British and German guidelines and also guidelines from other countries (France, Italy, Russia, United States, ...) it is of interest to point them out because guidelines in Europe should be harmonised due to the fact that for example data are describing the accident rates are generally better in England than in Germany. In general this comparison should not only be applied to the guidelines. Important are measuring at the different road stations. These should be made on roads which are built in coordination with the actual guidelines. As not to have too much trouble with the measuring comparable roads were chosen. In Germany it was reduced to the Rhein-Main area. The following roads for which the measurement was taken were examined concerning the road design, sight distance and the speed. The data in table 1 give the description of the investigated roads:

Road Department Aschaffenburg, Germany:
- County road MIL 26 Eschau – Wildensee (F)
- State road St 2307 Hösbach – Schimborn (E)
Road Department Bensheim, Germany:
- State road L 3120 Affolterbach – Airlenbach (D)
- State road L 3408 Birkenau – Löhrbach (G)

Road Department Weilburg, Germany:
- County road K 412 Ahausen – Drommershausen (A)
- State road L 3031 Würges – Steinfischbach (C)
- State road L 3449 Niederselters – Weilmünster (B)

Road Direction Strasbourg, France
- National Road 63, By-pass Soufflenheim

Lancashire County Council, United Kingdom:
- A 59(T) Whalley – Gisburn (Clitheroe By-pass) (H)
- A 6068 Sabden – Nelson (Padiham By-pass) (I)

The required planning documents and data were given by the road departments. It was also possible, beside the comparison of guidelines to examine the friction factor of the countries. Due to the development of car productions, the road design and the driving behaviour it has often be required to actualise these data. For example the data in Germany were 20 years old, in England 15 years old.

<table>
<thead>
<tr>
<th>Investig. road</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
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</thead>
<tbody>
<tr>
<td>Length</td>
<td>2682</td>
<td>4169</td>
<td>5633</td>
<td>5509</td>
<td>3329</td>
<td>6350</td>
<td>3100</td>
<td>2500</td>
<td>2374</td>
</tr>
<tr>
<td>Width of Carriageway</td>
<td>6,0</td>
<td>6,0</td>
<td>8,5</td>
<td>6,0</td>
<td>7,5</td>
<td>5,5</td>
<td>6,0</td>
<td>7,3</td>
<td>7,3</td>
</tr>
<tr>
<td>Width of strip footing</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
<td>1,0</td>
<td>1,0</td>
<td>1,5</td>
<td>1,5</td>
<td>1,5</td>
</tr>
<tr>
<td>&quot;Kurvigkeit&quot;</td>
<td>168</td>
<td>68</td>
<td>133</td>
<td>209</td>
<td>56</td>
<td>104</td>
<td>267</td>
<td>67</td>
<td>63</td>
</tr>
<tr>
<td>Bendiness</td>
<td>151</td>
<td>61</td>
<td>119</td>
<td>188</td>
<td>50</td>
<td>94</td>
<td>204</td>
<td>60</td>
<td>57</td>
</tr>
<tr>
<td>Layout Constraint</td>
<td>28</td>
<td>28</td>
<td>19</td>
<td>28</td>
<td>23</td>
<td>28</td>
<td>28</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Alignment Constraint</td>
<td>17</td>
<td>11</td>
<td>15</td>
<td>18</td>
<td>12</td>
<td>14</td>
<td>20</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>V85,nass (RAS-L)</td>
<td>76</td>
<td>85</td>
<td>91</td>
<td>74</td>
<td>95</td>
<td>79</td>
<td>70</td>
<td>94</td>
<td>93</td>
</tr>
<tr>
<td>V85,wet (HLD, TD 9/81)</td>
<td>78</td>
<td>84</td>
<td>90</td>
<td>74</td>
<td>90</td>
<td>80</td>
<td>70</td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td>V85,wet, Measured</td>
<td>75</td>
<td>99</td>
<td>100</td>
<td>83</td>
<td>98</td>
<td>94</td>
<td>81</td>
<td>100</td>
<td>93</td>
</tr>
</tbody>
</table>

Table 1: Data and results of measurements at the investigated roads
Since there were no data about the sight distances they had to be measured corresponding to the guidelines. There are not only differences between Germany and England but also to other countries, which can partly be explained by the different year of appearance of the guidelines. A survey of the determination of sight distances in the different countries is given in table 2. Simple procedures have been used for years to ascertain the existing sight distances in the roadside environment. These methods have large disadvantages concerning quality, efficiency and safety. The use of electro-optical measurement of distances and registering in electronical field books is an essential advantage. Furthermore a direct processing of the data is possible. The existent measure equipment was improved and automised in the course of this examinations. Safeguarding steps had to be taken since all measurements which were taken in full traffic flow. The measurement is similar to a construction site which moves constantly with slow speed. The measuring device has to be checked by the responsible authority.

<table>
<thead>
<tr>
<th>Country</th>
<th>Guideline</th>
<th>Height of Eye (cm)</th>
<th>Height of Object (cm)</th>
<th>Determinant Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>RVS 3.23 (1981)</td>
<td>100</td>
<td>100</td>
<td>$V_P$</td>
</tr>
<tr>
<td>Canada</td>
<td>GDSCRS (1976)</td>
<td>105</td>
<td>130</td>
<td>Design Speed</td>
</tr>
<tr>
<td>Denmark</td>
<td>64 Standard (1964)</td>
<td>120</td>
<td>130</td>
<td>$V_e$</td>
</tr>
<tr>
<td>France</td>
<td>ICTARN (1994)</td>
<td>100</td>
<td>100</td>
<td>$V_{85}$</td>
</tr>
<tr>
<td>Germany</td>
<td>RAS-L (1995)</td>
<td>100</td>
<td>100</td>
<td>$V_{85}$</td>
</tr>
<tr>
<td>Japan</td>
<td>Highw.Des.Man.(1983)</td>
<td>120</td>
<td>120</td>
<td>Design Speed</td>
</tr>
<tr>
<td>Sweden</td>
<td>TU 124 (1981)</td>
<td>110</td>
<td>135</td>
<td>Design Speed</td>
</tr>
<tr>
<td>Switzerland</td>
<td>SN 640 090a (1992)</td>
<td>100</td>
<td>--</td>
<td>$V_P$</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>TD 9/81 (1981)</td>
<td>105</td>
<td>105</td>
<td>Design Speed</td>
</tr>
<tr>
<td>United States</td>
<td>AASHO Policy (1984)</td>
<td>107</td>
<td>130</td>
<td>Design Speed</td>
</tr>
</tbody>
</table>

Table 2: Basic Values for the Determination of Existing Sight Distances in Different Countries

A floating car was used on all German roads which were investigated parallel to the measurement which has already been named. With the help of four video cameras every part of road equipment was recorded in its “Road-Video-System” (SVS). The SVS is used for registering the condition of the road and for the inventory of the road equipment. By comparing the results of the measurements, it was possible to make conclusions about the accuracy of measurement.
To be able to compare the results it was important that the outside conditions were the same at all measurements. This was achieved by measurements which lasted between three and six hours. The minimum of 200 vehicles with a net time gap of five seconds and more were measured for each direction of driving on each investigated road. This amount of measurements gives a sufficient picture of the actual situation. The evaluation of the results was made at University of Applied Sciences Darmstadt with an available program of statistics. The usual parameters of the relative frequency and the relative cumulative frequency were used.

Conclusions

Clear differences in the philosophy of the guidelines can be seen between the German and the British road design guidelines. But the results of the measurement of the driver behaviour at the different roads are similar in spite of the different dispositions. The similar results in both countries concerning the speed $V_{85}$ which can be expected out of the two guidelines is shown in table 2. There is an enormous difference between these theoretic acquired data and those which were actually measured. The speeds which were actually driven are always higher than those as calculated. The following statements can be made out of these comparisons:

- the theoretically acquired data are similar in the investigated countries although the inquiries are different.

- They are below the measured value.

- The influence of sight distances upon the choice of speed is underestimated.

- Due to the importance of speed for the road safety old data should be updated in the countries more frequently.

Further Steps

Including current partnerships in research and education the investigation of roads in the countries Italy, Russia and perhaps the United States shall be extended. In the countries Germany, United Kingdom and France the measurements will be updated.
The results are important for future models of design elements and also for the improvement of road safety. Especially Russia with a high increase of the car ownership rate needs a general revision of the guidelines.

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THE TRAINER PROJECT – DEVELOPMENT OF A NEW COST-EFFECTIVE PAN-EUROPEAN DRIVER TRAINING METHODOLOGY AND HOW TO EVALUATE IT.

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Abstract

The main purpose of the TRAINER project is to develop a new cost-effective Pan-European driver training methodology, based on computer based interactive multimedia and simulator technology, which will pay significant attention not only to gain experience of driving and handling the car, but also to the enhancement of risk awareness of learners drivers. For this purpose three different simulation tools will be developed. Each set will consist of a multimedia info-box and a low-cost/medium-cost driving simulator. A number of scenarios for application in the different simulation environments will be developed, which addresses the most important needs of learner drivers. They have been structured in accordance with the four hierarchical levels of the GADGET-matrix:

- Level 4. Goals for life and skills for living
- Level 3. Goals and context of driving
- Level 2. Mastering traffic situations
- Level 1. Vehicle manoeuvring

In order to be able to assess the TRAINER tools impact on traffic safety, not only a set of driver performance pilots needs to be performed but also another set of pilots. In these pilots driver behaviour, i.e. what the driver in fact does, in a critical scenario should be measured. However, the drivers’ behaviour is not only influenced by his / her driving performance skills, but also on the hazard perceptual abilities of the driver. Hence, based on the assumption that driving skills is controlled for by the driver performance pilots, the results from the traffic safety impact pilots will address the question on whether or not increased hazard perception has been achieved by use of the TRAINER tools.

In order to get a valid and reliable measurement of driver behaviour, the driver must be able to be exposed to what he or she perceives as a potential hazard and be able to react accordingly. At the same time dangerous behaviour must not result in real world accidents or damage. For these reasons conducting driving simulator experiments offers the best solution, although a 100 per cent validity can not be expected. However, performing part of the assessment in real traffic environment, while assessing visual search strategies, can reduce this lack of validity with respect to real traffic behaviour, by measuring eye movements.

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Introduction
This paper describes the TRAINER\textsuperscript{1} concept in general, as well as the design of the pilot evaluations. For this reason some sections in the paper are presented as summaries and have a reference to final deliveries from the TRAINER project.

The Public Health Perspective
Throughout Europe 15,000 young people die each year due to road accidents (Gadget Final Report, 2000). In many European countries traffic accidents are even the leading cause of death of young people. Regarding their fatality rate, young drivers are over-represented in comparison to other age groups of drivers. The graphical representation of the fatality rate plotted against driver age shows a distinct U-shaped curve; fatality rates are highest for young drivers, as well as for old drivers (70+ years old) (Evans, 1991). The size of the problem makes clear that action is needed. It is important, yet difficult, to identify the causes of the high accident risk of young novice drivers, since many factors can be imagined to contribute to their high accident risk. Moreover, almost none of these factors seem to operate alone.

Two factors, age and experience, are difficult to separate, but both seem to contribute to the high probability of being involved in an accident. The task of driving is extremely complex, even though drivers frequently have the impression it is not. Acquisition of the basic vehicle handling skills is relatively straightforward. It has been suggested that novice drivers learn well the traffic rules and learn to shift gear, accelerate, steer and brake after only 15 hours of driving (Hall & West, 1996). These skills are important for driving but in order to drive safely, drivers should also be able to perform higher-order perceptual and cognitive skills.

A novice driver has to learn what information is important to pay attention to, to judge incoming cues on their relevance, and has to evaluate the information in terms of potential danger or hazard. Especially these skills take time to develop and they require a lot of practice and experience. Imagine young novice drivers learning to drive and at a certain moment in time they are able to control the car with a minimum of mistakes. As long as the environment co-operates and as long as these young novice drivers do not encounter situations in which they have to avoid an accident, their idea of being a good driver is certainly supported.

There is clearly the need to develop a practical method to make the driver aware of aspects such as his/her own and other road users limitations, vehicle and infrastructure limitations, lack of experience, the problem of overestimating one’s driving ability, the feedback and risk compensation process, etc. A typical example is the fact that experienced drivers tend to fixate their eyes higher in the visual screen that inexperienced drivers (Carter & Laya, 1998). For this, the driver trainee should be placed in situations where he/she is shown that his/her own decisions were based on aspects such as overconfidence or risk compensation.

From the above, we can say that there is a pressing need for developing a new European driver training methodology, which would be focused more on the typical novice driver accidents, and to include the use of new telematic aids.

\textsuperscript{1} System for driver Training and Assessment using Interactive Evaluation tools and Reliable methodologies, GRD1-1999-10024
Young Driver’s Accidents

A literature review of young driver’s accident involvement (Hoeschen & Bekiaris, 2000) has shown that young drivers’ accidents are typically single vehicle accidents and are often preceded by risky driving. Young drivers are not over-represented in alcohol accidents. In comparison with older drivers they are even under-represented. Exception to these findings is the weekend-nights in which the young drivers tend to be over-represented. Young drivers are often characterised by driving too fast for prevailing conditions. This may also account for the high proportion of accidents in curves, and single accidents. Young drivers are more often involved in the more serious accidents, partly because of the presence of many passengers. Furthermore, young drivers drive more often with inappropriate speeds. Speed is directly related to the seriousness of the accident.

Various sources in the literature (Hoeschen & Bekiaris, 2000) emphasise the fact that learning manoeuvring skills does not contribute to safe driving and reducing accident rates of novice drivers. There is evidence that young drivers can have superior vehicle handling skills and still have many crashes (Evans 1991). It is suggested that teaching safe driving strategies and training recognition of hazards and of higher order skills will be promising in reaching the aim of lower accident rates with novice drivers.

The Need For A New Training Curricula

Attempts to teach trainees safe-driving strategies during training often failed, probably because the information processing capacity of novice drivers is already overloaded by vehicle control and interacting with other traffic participants (Hoeschen & Bekiaris, 2000). Trainees have to make conscious decisions for every move and every action they take, so they are not able to use improvements of defensive or risk minimising strategies.

Another finding is that drivers after extensive skill training underestimate the risk in a certain situation and overestimate their manoeuvring skills in negotiating certain situations. This was found for example with Scandinavian skid-control-courses that appeared to increase traffic accident rates significantly. This negative effect was interpreted as a result of the focus on coping with skidding situations instead of focussing on how to avoid these situations. The focus on coping seems to create reduced respect for low friction and results in overconfidence of the own skills, leading to more risky driving and more accidents.

Indeed, as Evans (1991) and other authors have emphasised, it is not crucial for safety how skilled a driver is, but to what extent drivers use their skill in driving safely. In some countries (e.g. Germany) theory lessons have started to focus on such higher-level aspects of decision-making and on motivational tendencies. Specific themes are search for independence and autonomy, coping with impatience, self-assertion in groups, behaviour in competitive situations, making decisions and time planning. The idea behind these approaches is that driver training should focus not only on skills and knowledge, but also on driver attitudes.

Taking these results together, it appears necessary to train cognitive skills and to teach trainees to assess their own skills so that they can better judge the consequences of what they chose to do. Recent research (e.g. in USA and Australia) led to the development of PC-based Training programs, in which trainees are instructed to estimate the outcomes of critical and hazardous situations. Trainees make their own choices and then experience the results of their actions. Unfortunately, unsafe driving choices are often rewarded by lack of negative outcomes in the "real world". In this program, risky behaviour has immediate consequences.
So, these programs aim at accelerating the development of safety skills that novice drivers lack because of inexperience and otherwise have to learn only gradually in practice.

An even more powerful way to let trainees experience the consequences of their behaviour is having them drive in driving simulators. The trainees ‘drive’ the car themselves and react to various situations in realistic ways. The simulator enables driving in hazardous and accident-prone scenarios that cannot be experienced in real-car driving. Even if trainees have not yet fully automated vehicle-handling skills it appears that in a driving simulator they can be taught to improve their anticipation of dangerous situations (by proper interpretation of the wide range of visual information of the traffic environment). They can also learn to avoid hazardous situations by a defensive driving style. Further advantages of driving simulator are the possibilities to:

- control the type and timing of training events,
- adapt the training task to the performance of the trainee,
- provide augmented cueing and feedback,
- record and diagnose trainee performance,
- automate the process of training and instruction,
- reduce the amount of practice by providing immediate feedback.

So, recent research indicates that accidents of novice drivers are caused more by false personal tendencies than by lack of handling skill. Young drivers often have risky habits (e.g. testing limits of own skill), safety-negative motives (like competing or pleasure), and are prone to social pressure by peers (use of alcohol and drugs etc.). Exercises should be developed to make trainees aware that assessment of their own abilities to negotiate critical situations may be false, especially in the beginning of a driving career. Another promising way to teach safe driving behaviour is including group discussions into the curriculum, in which trainees are asked to evaluate their own attitudes and the consequences on decisions taken during driving. Trainees should discover themselves, by discussion, observation and activity, the validity of their own beliefs and the critical nature of the decisions that they have to make in modern traffic.

As found in the road-safety research literature of the last two decades there is a shift from emphasising training manoeuvring skills to training higher-order skills, i.e. recognition and anticipation skills, including risk perception, as well as self-assessment. It has been demonstrated that connecting practical exercises to theory and evaluation of one’s own behaviour may be effective.

**The GADGET-Matrix: Hierarchical Levels Of Behaviour And Referring Structure Of Driver-Training Contents**

The GADGET-matrix is based on the assumption that the driving task may be described as a hierarchy. The idea of the hierarchical approach is that abilities and preconditions in a higher level influence the demand and preconditions on a lower level. The hierarchy is developed by Keskinen (1996) and shows many similarities with the Michon hierarchy. The most important difference is the addition of a fourth level relating to personal preconditions and ambitions in life in general, which have shown to be of great importance for driving and road safety. The following four levels are described by Keskinen and were later also applied in the EU-project GADGET (Hatakka et al. 1999) (see Table 1):
The highest level refers to personal motives and tendencies in a broader perspective. This level is based on knowledge that lifestyles, social background, gender, age and other individual preconditions have an influence on attitudes, driving behaviour and accident involvement.

On the next level, the focus is on the goals behind driving and context in which driving is performed. The focus is on why, where, when and with whom driving is carried out. Examples on more detailed aspects are the choice between car and bus, daytime or nighttime driving, rush hours or not, decision to drive under the influence of alcohol, fatigue or stress etc., all in relation to purpose of the trip.

The next level is about mastering driving in traffic situations, which are defined as more limited than the driving context above. A driver must be able to adjust his/her driving in accordance with the constant changes in traffic, for example in junctions, when overtaking or when encountering unprotected road users. To be able to identify potential hazards in traffic is also on this level. Driver education and training is traditionally focusing on this level.

The bottom level is focusing on the vehicle, its construction and how it is manoeuvred. To know how to start, shift gears and stop the car good enough to be able to use the car in traffic belongs to this level, as well as more complex evasive manoeuvres, reducing skids on low friction and understanding the laws of nature. The functioning and benefits of injury preventive systems, such as safety belts and airbags also belong here.

A safe driver is, however, not only skilled but also aware of risks and of own abilities and preconditions. In order to cover these different dimensions the matrix includes three dimensions as follows:

- Knowledge and skills
- Risk increasing factors
- Self-assessment

The content of the first column describes the knowledge and skills that a driver needs for driving under normal circumstances, that is, on the lower hierarchical levels how to manoeuvre the car, how to drive in traffic and what rules must be followed. On the higher levels the column relates to how trips should be planned and how personal preconditions may influence behaviour and safety.

In the second column about risk increasing factors the focus is on awareness of aspects of traffic and life that can be associated with higher risk. On the basic level it may be worn-out tyres, poor brakes, lack of routine in performing basic manoeuvring etc. Higher in the hierarchy the column refers to risky driving in darkness, on low friction, among unprotected road users, excessive speeding, mental overload etc. It also relates to dangerous motives and risk increasing aspects of lifestyle and personality.

The third column is about how the driver is assessing his/her own situation on the four levels. It points out the calibration of own skills on the basic levels and awareness of own personal
The cells in the matrix thus define frames for definition of detailed competencies that is needed in order to be a safe driver. The matrix may be used for defining educational goals and educational content in driver education and training. The suggestion from the constructors of the matrix is that driver training strives at covering as much as possible of the whole matrix, not only the lower leftmost cells that traditionally are covered. The matrix is used in the

- preconditions and tendencies, as well as abilities in decision making about trips and in life in general on the upper levels.

Table 1 The GADGET-matrix (Hatakka et al. 1999)

<table>
<thead>
<tr>
<th>Hierarchical levels of behaviour</th>
<th>Essential curriculum</th>
<th>Risk-increasing factors</th>
<th>Self-evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals for life and skills for living (general)</td>
<td>Knowledge and skills concerning: knowledge about/ control over how life-goals and personal tendencies affect driving behaviour.</td>
<td>Risky tendencies involving: acceptance of risks, self-enhancement through driving, high level of sensation seeking, complying with social pressure, use of alcohol and drugs, values, attitudes towards society</td>
<td>Self-evaluation/ awareness of: personal skills for impulse control, risky tendencies, safety-negative motives, personal risky habits.</td>
</tr>
<tr>
<td>Driving goals and context (journey-related)</td>
<td>Knowledge and skills concerning: effects of journey goals on driving, planning and choosing routes, evaluation of requested driving time, effects of social pressure inside the car, evaluation of necessity of the journey.</td>
<td>Risks connected with: driver’s condition (mood, BAC, etc.), purpose of driving, driving environment (rural/urban), social context and company, additional motives (competitive, etc.).</td>
<td>Self-evaluation/ awareness of: personal planning skills, typical driving goals, typical risky driving motives.</td>
</tr>
<tr>
<td>Mastery of traffic situations</td>
<td>Knowledge and skills concerning: traffic regulations, observation/selection of signals, anticipation of the development of situations, speed adjustment, communication, driving path, driving order, distance to others/safety margins.</td>
<td>Risks caused by: wrong expectations, risk-increasing driving style (e.g. aggressive), unsuitable speed adjustment, vulnerable road-users not obeying regulations, unpredictable behaviour, information overload, difficult conditions (darkness, etc.), insufficient automatism or skills.</td>
<td>Self-evaluation/ awareness of: strong and weak points of basic traffic skills, personal driving style, personal safety margins, strong and weak points for hazard situations, realistic self-evaluation.</td>
</tr>
<tr>
<td>Vehicle manoeuvring</td>
<td>Knowledge and skills concerning: control of direction and position, tyre grip and friction, vehicle properties, physical phenomena.</td>
<td>Risks connected with: insufficient automatism or skills, unsuitable speed adjustment, difficult conditions (low friction, etc.).</td>
<td>Awareness of: strong and weak points of basic manoeuvring skills, strong and weak points of skills for hazard situations, realistic self-evaluation.</td>
</tr>
</tbody>
</table>
development of a new national curriculum for the Swedish driver education (Gregersen et al., 1999). In the TRAINER project the matrix is used for definition of educational content as a base for development of new educational methods and applications.

The Trainer Tools

The main purpose of the TRAINER project is to develop a new cost-effective Pan-European driver training methodology, based on computer based interactive multimedia and simulator technology, which will pay significant attention not only to gain experience of driving and handling the car, but also to the enhancement of risk awareness of learners drivers. For this purpose three different simulation tools will be developed. One is a multimedia tool and the other two are low cost and medium cost simulators. Four full sets of TRAINER tools will be developed and installed at Belgium/Netherlands, Spain, Sweden, and Greece. Each set will consist of a multimedia info-box and a low-cost/medium-cost (both versions) driving simulator.

The multimedia training tool will familiarise novice drivers with the basic principles of steering and driving a vehicle. Experience will be gained in simulated environment, thus relieving the road network and enhancing road safety. It will also provide to novice drivers a better overview and understanding of road hazards. This s/w is expected to support the theoretical training and assessment of drivers, in order to extend it from a simple traffic rules check to actual handling of complex traffic scenarios. The s/w will be integrated in a form of an information kiosk.

The low-cost simulator is composed by a driving stand, the driving computer with integrated image generator, and a separate monitor, which is put on top of the driving stand in front of the steering wheel. The horizontal view angle is 40 degrees. The driving computer and image generator is accommodated inside the cabin. The driving stand comprises of a wooden cabin, the drivers seat, a dashboard with instruments, and operational elements as accelerator-pedal, brake-pedal, clutch-pedal, handbrake, gear stick, indicator lever, headlight switch, windshield wiper lever, ignition key, horn button and steering wheel. The shaft of the steering wheel is connected to an electrical motor and pulse generator. The motor generates the torque onto the steering wheel, and the pulse generator supplies the input for an incremental steering wheel angle measurement counter. A direct current motor with worm gear, ratio = 70:4 = 17,5 is used. The worm gear box is integrated at the motor. In order to firstly have a sufficiently high torque on the steering wheel and secondly to be able to control the steering wheel torque in a natural range, a control unit with a maximum of 6 A is used, which creates a maximum torque of about 6 Nm. The output signal of the PC is supplied to the input/output interface board and from there to the control device of the motor. It is possible, to realize by software any characteristic of the steering wheel in dependency to the steering wheel angle and the speed of the car. For data gathering, gravity sensors are used for the pedals. The simulated gearbox is equipped with switches. The mechanical forces on pedals, gear stick and steering wheel are nature-like. The forces and strokes of the pedals may be changed by mechanical mediums. Several software modes and scenarios can be pre-selected by the computer menu, using a small control unit with two buttons. For the noises a PC-sound-card, an audio amplifier and a loudspeaker, 20 W, in a closed, screened box is used.
The medium-cost simulator differs from the low-cost simulator by the use of three monitors, a vibration system and a simple motion system. Each of the two peripheral monitors has its own PC as image generator. The visual system is a fixed screen system, which means that, also with motion of the driving stand by the below described motion support, the picture screens do not move.

There is a vibration of the steering wheel, correlated to the vehicle engine RPM. A long-life excenter motor is connected to the shaft of the steering wheel. The shaft is buffered to the main frame of the simulator by rubber-cylinders. The mounting of the vibration motor to the steering wheel compared to a vibration of the whole simulator has the advantages that the excenter motor needs less power. The bottom plate of the simulator does not vibrate, so that the driving computer may be integrated in the simulator cabin. The vibration device does not affect the plastic cover with the two levers for light, horn and windshield wiper. Moreover, it does not move the dashboard.

The motion system is a support unit, which can be put under the driving stand. It is controlled by the driving computer, improves the driving feeling at steering and is expected to reduce possible motion sickness. The support construction has the size 78 x 78 cm. It is able to shift the top plate of the support unit in accordance to the lateral acceleration of the simulated car. There is a reduced probability for motion sickness, as the movements are short-stroked. The delay time between the causing event and the movement of the motion system will be extremely short, so that not only the general feeling of driving will be improved, but especially the steering behaviour, which generally is poor in simulators, will be stabilized. An advantage of this modular motion support is that it may be used as well for the simulation of longitudinal acceleration forces, just by turning it around 90 degrees.

A number of scenarios for application in the different simulation environments is developed, which addresses the most important needs of learner drivers, based on the Gadget matrix, as described in the next chapter.
The TRAINER Tool Scenarios
The development and selection of scenarios has followed a structured process, which started with brainstorming and ended with a structured, full description of a selection of scenarios with high priority. It is important to emphasise that going through the whole structured process has been regarded as crucial in this work. The idea behind the process was to base the scenario development on the actual needs of young novice drivers. The needs were defined through literature reviews and workshop input. These needs were structured through the use of the theoretical framework that was offered by the GADGET matrix. The steps of the selection process are described below:
1. Literature review on novice drivers’ problems, behavioural and social aspects related to their driving and accident involvement.
2. Literature review concerning accident types and analysis of accident statistics with regard to novice drivers from a selection of countries.
3. Literature review and surveys among driver instructors with regard to gaps perceived in present driver education systems.
4. Collection of suggestions and ideas regarding steps 1-3 above in a workshop in Brussels, with invited driver instructors, simulator producers and other stakeholders.
5. Decision to use the GADGET matrix as a theoretical framework for defining the competencies that a driver needs, in order to be a competent and safe driver.
6. Brainstorming and free input of ideas for scenarios from all project partners, from participants in the workshop in Brussels and from visitors of the TRAINER web site.
7. Sorting of these suggestions into the four levels of the GADGET matrix. In total 97 different scenarios were suggested
8. Design of a method to prioritise and select scenarios. The method includes the following steps:
   - Assessment of each scenario on a 1-10 scale concerning its importance regarding needs of novice drivers.
   - Assessment of each scenario on a 1-10 scale concerning its suitability for the multimedia tool.
   - Assessment of each scenario on a 1-10 scale concerning its suitability for the simulator tools.
   - Calculating suitability times importance of each scenario, resulting in a score between 0 and 100.
   - Selection of scenarios with the highest scores for application in the simulator.
9. Full descriptions of 96 selected scenarios.

TRAINER Tools Pilot Evaluation
In a test procedure, aiming to evaluate the TRAINER tools, 60 learner drivers will initially undergo the standard theoretical driver education in a local driving school. 30 of them (the trial group) will be trained for an additional 2-3 hours using the multimedia tool. All 60 people will then be tested using the multimedia s/w for about 15 minutes and also undergo the normal driving license theoretical test. The design of these tests is presented in Figure 2
In the second stage, all 60 learner drivers will be trained on the road by the local driving school using a driving school vehicle. The training time of each will last until the driving instructor is satisfied that the candidate is fit for the driving license test. The amount of training that is needed will be stored as a parameter for use as an independent variable in the evaluation.

The actual design of the training procedure will, however be adjusted to the national training principles. In some countries the theory is educated separately and in some it is integrated with practice.

After this training, the trial group will be randomly divided into two groups of 15 drivers. Both groups will achieve an additional 2-3 hours training, one in the low-cost and one in the medium-cost driving simulator. All these 30 drivers and the 30 in the control group will be tested in the low cost and the medium-cost simulators. All 60 drivers will also undergo a driving license practical examination.

*) National theory test will be conducted at this point or at any other point as regulated in each participating country

**Figure 2: Design of the Evaluation of the Training Tools**

*Trial group (n=30)*
- Normal theory education
- Multimedia learning
- National theory test*
- Theory test in MM box
- Normal driver training
- LC simulator learning (n=15)
  - National driving test
  - Pilot tests in LC/MC sim.
  - Safety impact pilots
- MC simulator learning (n=15)
  - National driving test
  - Pilot tests in LC/MC sim.
  - Safety impact pilots

*Control group (n=30)*
- Normal theory education
- National theory test*
- Theory test in MM box
- Normal driver training
- National driving test
- National driving test
- National driving test
- National driving test
- Pilot tests in LC/MC sim.
- Pilot tests in LC/MC sim.
- Pilot tests in LC/MC sim.
- Safety impact pilots

*) National theory test will be conducted at this point or at any other point as regulated in each participating country
The pilot evaluation test hypotheses include the use of the TRAINER tools internal learner driver records database as independent variables describing duration and quality of the training education. Their actual relation to the traffic safety will not be able to be measured within the project three-year duration. A good indication of this will, however, be provided by the final pilots, i.e. “Safety impact pilots”, which are aiming at evaluating the safety impacts of the TRAINER tools.

In these “Safety impact pilots” driver behaviour, i.e. what the driver in fact does in a critical scenario, as opposed to what the driver can do, i.e. driving skills (Evans 1991), will be measured. The driver’s behaviour is, however, not only influenced by his/her driving performance skills, but also by the hazard perceptual abilities of the driver. Hence, based on the assumption that driving skills are controlled for by the driver performance pilots, i.e. “Pilot tests in LC/MC sim.” in Figure 2, the results from the traffic “Safety impact pilots” will address the question on whether or not increased hazard perception has been achieved by utilizing the TRAINER tools.

However, in order to get a valid and reliable measurement of driver behaviour, the driver must be able to be exposed to what he or she perceives as a potential hazard and be able to react accordingly. At the same time dangerous behaviour must not result in real world accidents or damage. For these reasons conducting driving simulator experiments offers the best solution, although a 100 per cent validity cannot be expected. But, performing part of the assessment in real traffic environment, while assessing visual search strategies, this lack of validity with respect to real traffic behaviour can be reduced. Hence, for the design of the traffic “Safety impact pilots” both a simulator study and a real world traffic visual search strategy study will be performed, in order to obtain as high validity as possible without jeopardising the subjects’ safety. A pre-study for the “Safety impact pilots” has already been made (Falkmer & Gregersen, 2001c), based on combined quantitative and qualitative approach (Falkmer & Gregersen, 2001a; Falkmer & Gregersen, 2001b).

Lastly, a thorough technical, strategic, usability, sensitivity and socio-economic analysis of evaluation TRAINER results will also be conducted.
References


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THE EFFECTS OF DIABETES AND LOW BLOOD SUGAR LEVELS ON DRIVING BEHAVIOUR: COMPARISON OF DIABETICS AND NON-DIABETICS.

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Abstract
Under contract with the University Medical Centre, Utrecht, TNO Human Factors has conducted research to investigate the effect of diabetes on driving behaviour. In a driving simulator experiment, patients with diabetes and non-diabetics were confronted with various traffic situations. The subject groups always drove the conditions twice. In this, the patient groups drove the route once with euglycaemia (a normal blood sugar level) and once with hypoglycaemia (low blood sugar level). The non-patient group drove the route twice with a normal blood sugar level. Subjects did not know in what condition their blood sugar level would be decreased to the level of hypoglycaemia. In the analysis of the diabetic group, difference was made between people who were aware of their blood sugar level being low and those who did not notice the status of hypoglycaemia.

Ninety subjects participated in a driving simulator experiment. Subjects drove on the motorway, a rural road and a city road. During normal driving situations, some critical incidents were encountered (e.g. braking lead vehicle, deciding who has the right of way, coping with curves). During driving, behavioural variables were measured. These variables were Time-to-Line-Crossing, Time-To-Collision, crossing road markings, response times to critical situations and responses to a secondary task. By comparing driving performance between non-patients and patients, and between a normal blood sugar level and hypoglycaemia, the effects of diabetes on driving performance and traffic safety were established. The results showed that in case of a low blood sugar level in Type II diabetics (non-insulin dependent), there is a clear decrease in performance, although some of the effects are also present in that type of diabetics with normal blood sugar levels. Type I (insulin dependent diabetics) diabetics did not show any decreased driving performance, not even with low blood sugar levels.

1 Introduction
In the Netherlands alone, about 300,000 people suffer from diabetes. About 20% of those patients is insulin dependent (Type I diabetics) and the remaining part is non-insulin dependent.
(Type II diabetics), using a diet and sometimes oral medication. A lot of European countries have special regulations concerning driving licenses of diabetics, because of the common belief that diabetics have a higher risk of being in an accident due to an increased risk of hypoglycaemia (low blood sugar level), visual limitations and sometimes even neurological handicaps or cardiovascular complications.

Until now, objective research about the possibly negative effect of diabetes on driving behaviour has not been conducted. In the literature, no consensus about increased accident risk exists (for example Veneman, 1996). There are even studies that suggest that diabetics have a lower risk (Ysander, 1970; Eadington & Frier, 1989). One earlier study (Cox, Gonder-Frederick, Kovatchev, Julian & Clarke, 2000) showed that driving performance decreased in patients with hypoglycaemia. However, the results cannot be generalised since no group of non-patients was used, the simulator was of low-fidelity and no distinction was made between diabetics who are aware and who are not aware of the low blood sugar level. Some diabetics are aware of the presence of hypoglycaemia when this occurs, while other do not notice this (unaware). Being aware or unaware of hypoglycaemia may be an important risk factor in traffic. Diabetics who are unaware may not compensate for the possible negative effects involved.

2 Driving Simulator Study

Under contract with the University Medical Centre in Utrecht, TNO Human Factors conducted a driving simulator study (for a detailed description of the driving simulator see Hogema & Hoekstra, 1998; Hoekstra, van der Horst & Kaptein, 1997), to assess the effect of diabetes mellitus on driving performance, in particular when being afflicted by hypoglycaemia.

2.1 Subjects

Four groups of subjects were used: 24 subjects were part of the non-patient group, 24 subjects participated in the Type-I (aware) group, 21 in the Type-1 (unaware) group and 21 in the Type-II group. All subjects were recruited by the University Medical Centre. All subjects had their driver's license for at least 2 years, drove a minimum of 6000 km/year and their visual acquity was at least 0.8. Whether subjects were aware or unaware was measured with the Clarke checklist (see Sels, 2000). Both male and female subjects were included in the experiment.

2.2 Task

The task of subjects was to drive in the driving simulator in three different environments: a motorway, a rural road, and a city road. There was normal driving on these roads, but on several occasions, some critical things happened, such as a lead vehicle that braked, a package falling from a truck, some sharp curves, a vehicle that suddenly drove away just before passing it, and a crossing pedestrian. Also subjects had to perform a secondary task, in which they had to respond to the appearance of a red dot on the simulator screen, which could be detected with peripheral vision
(subjects did not have to look at the dot). This secondary task is an indication for the workload of the primary task (that is driving). This secondary task is called the Peripheral Detection Task (for a detailed description of the Peripheral Detection Task see Van Winsum, Martens & Herland, 2000). This secondary task was to get some extra information in addition to driving performance. This measure was used in order to see whether the driving task was more strenuous or less strenuous for diabetics.

2.3 Dependent variables
Driving behaviour was measured by means of speed, standard deviation of lateral position, percentage of time the Time-to-Line-Crossing (a measure (in s) that indicates how close a driver is to crossing a road marking) was below 1 second and the percentage of time that the road markings was actually exceeded (on the left side as well as on the right side). Also steering behaviour was measured and performance on the Peripheral Detection Task (RT to the appearance of the red dot and the percentage of missed signals).

2.4 Procedure
All subjects received an intra-veinal tube in order to control the blood sugar level. This was done for the non-patients as well as for the patients. The first ride was always a practice ride of about 10 minutes to get used to the driving simulator. All subjects drove this practice ride under euglycaemia (about 5.0 mmol/l). After this, a one hour break was used in order to check the blood sugar level. After this one hour break, subjects would drive the motorway, rural road and city road for 8 minutes each. Subjects did not know what level their blood sugar would be. After this first ride, another one hour break was used in order to lower the blood sugar level of the diabetics to about 2.7mmol/l (hypoglycaemia). The blood sugar of the non-patients was kept at the normal level. Subjects were not told that their blood sugar level was changed. In the second ride, the same types of roads were driven, although the critical scenarios were somewhat different in order to induce sufficient unpredictability. After this second ride, the blood sugar level was brought to a normal level and subjects were allowed to go home.

3 Results
To decide whether there was an effect of being a diabetic, the performance of each group of diabetics with their normal blood sugar level (first ride) was compared to the performance of the control group of non-diabetics with a normal blood sugar level (first ride). If there was a main effect of group, this effect could be attributed to being a diabetic.

To decide whether there was an effect of having hypoglycaemia, an interaction effect had to be identified. Just comparing the performance of the diabetics on the second ride (low blood sugar level) with the non-diabetics on the second ride (for the control group, the second ride was also with a normal blood sugar level) is not useful. If non-diabetics perform worse in their second ride
(normal blood sugar level), but diabetics performance better in their second ride (low blood sugar level), but still worse than non-diabetics, it not correct to conclude they perform worse (in comparison with the controls in their second ride) just by comparing them with the control group. On the other hand, just comparing them with their normal blood sugar level is also not correct, since any differences may be due to the fact that this is their second ride. Therefore, we look at the interaction between group (diabetics or non-diabetics) and ride (first or second ride). If there is an interaction, we conclude there is an effect of having a low blood sugar level in diabetics. If the controls perform worse in the second ride, and diabetics perform also worse in their second ride (which is with hypoglycaemia), we then conclude there is no effect of having a low blood sugar level, since the controls also performed worse and their blood sugar level was not changed.

3.1 Motorway
When driving on the motorway with a normal blood sugar level, only small differences were found between non-patients and diabetics.

Compared to the non-diabetics, Type I (aware) diabetics with a normal blood sugar level drove less often over the centreline marking (safer) (p<0.05). On all other performance criteria or workload, no difference was found between these groups.

For the Type I (unaware) diabetics with a normal blood sugar level, there was no difference between performance or workload on any of the indicators compared to non-diabetics.

When non-patients were compared with the Type II diabetics under normal blood sugar level, Type II diabetics responded somewhat slower to the secondary task (more workload, p<0.05), were swerving more inside their lane in critical situations (less safe) (p<0.03) and exceeded the right side marking more often in critical encounters (less safe) (p<0.05). Also, the percentage of time that the TLC was below 1 second was larger (less safe) under normal driving conditions compared to the non-patient group (p<0.03).

In case of a low blood sugar level, Type I (aware) and Type I (unaware) did not drive less safely or did not experience more workload than with a normal blood sugar level. Type II patients however responded more slowly to the secondary task (indicating more workload) compared to when driving with a normal blood sugar level (p<0.03).

3.2 Rural Road
Type I (aware) diabetics under normal blood sugar level showed a lower standard deviation in steering (safer) when overtaking another vehicle (p<0.01) and when approaching an intersection (p<0.04) compared to the control group of non-diabetics. The percentage of time the TLC was below 1 second was lower (safer) for the Type I (aware) under normal blood sugar level when overtaking a vehicle (p<0.03) compared to the control group.
For the diabetics Type I (unaware) under normal blood sugar level, the percentage of missed signals on the secondary task during overtaking was higher (more workload) than for the control condition ($p<0.04$). The percentage of time exceeding the centreline marking was lower (safer) compared to the control condition ($p<0.04$).

For Type II diabetics under normal blood sugar level, more signals were missed (higher workload) when negotiating a wide curve ($p<0.04$), overtaking a lead vehicle ($p<0.03$) or driving a straight road ($p<0.01$) compared to the non-diabetic group. Response times on the Peripheral Detection Task were also higher (more workload) when driving on a straight road ($p<0.01$) and when approaching an intersection ($p<0.01$) compared to the non-diabetic group ($p<0.01$). They spent more time driving over the centreline marking (less safe) when driving through a wide curve compared to non-patients ($p<0.03$).

In case of hypoglycaemia, Type I (aware) diabetics responded more slowly to the signals of the secondary task during normal driving ($p<0.05$), and when negotiating wide curves ($p<0.02$) compared to a normal blood sugar level. Type I (aware) drove less over the centreline marking (safer) compared to a normal blood sugar level in wide curves ($p<0.04$) and on straight roads ($p<0.04$).

For Type I (unaware) diabetics with a low blood sugar level, response times were higher (more workload) when negotiating a wide curve ($p<0.02$) or when driving on a straight road ($p<0.05$) compared to a normal blood sugar level.

With a low blood sugar level, the Type II diabetics missed more signals on the secondary task (higher workload) when driving on a straight road compared to a normal blood sugar level ($p<0.05$). Response times were also higher (more workload) with a low blood sugar level when negotiating a wide curve ($p<0.01$), driving a straight road ($p<0.01$) or when approaching an intersection ($p<0.02$). With a low blood sugar level, Type II diabetics also showed a larger standard deviation of lateral position (more swerving in their lane) compared to driving with a normal blood sugar level when negotiating a wide curve ($p<0.03$) and driving on a straight road ($p<0.05$). With a low blood sugar level, they drove more slowly (less safe) when overtaking a lead vehicle ($p<0.05$). More time was spent exceeding the centreline marking in wide curves ($p<0.01$) or the right side marking when driving a straight road ($p<0.01$) when their blood sugar level was low.

### 3.3 City road

For Type I (aware) diabetics with a normal blood sugar level, the response times to the secondary task were higher (more workload) than the control group of non-diabetics when negotiating a sharp curve ($p<0.01$), a medium curve ($p<0.02$), a wide curve ($p<0.03$) and when encountering a crossing pedestrian ($p<0.04$). A difference was found between Type I (aware) diabetics with a normal blood sugar level and non-patients, with Type I (aware) diabetics having a lower standard
deviation of the lateral position in sharp curves (safer) than non-diabetics (p<0.01). The standard deviation of the steering wheel was also lower (safer) for this diabetic group in sharp curves (p<0.04), in medium curves (p<0.02), in wide curves (p<0.04), when approaching a suddenly appearing vehicle (p<0.05) or when approaching a STOP sign (p<0.02).

For Type I diabetics (unaware), more signals were missed on the Peripheral Detection Task (higher workload) with normal blood sugar level compared to the control group when negotiating a medium-radius curve (p<0.03) or a wide curve (p<0.02). Response times were also higher (more workload) in sharp curves (p<0.02), in medium curves (p<0.01), and when encountering a crossing pedestrian (p<0.02). In sharp curves, the standard deviation of the lateral position was lower (safer) for Type I diabetics with a normal blood sugar level compared to non-diabetics (p<0.05). This was also the case for medium curves (p<0.05). The SD of the steering was lower (safer) for Type I (unaware) diabetics when driving in a sharp curve (p<0.01) and in a medium curve (p<0.04). The Type I (unaware) group under normal blood sugar level drove a little slower than the control group of non-patients when approaching a crossing pedestrian (p<0.03). The percentage of time that the TLC was lower than 1 second was lower (safer) for the diabetic group in a wide curve (p<0.01) and on a straight road (p<0.02).

With Type II diabetics with a normal blood sugar level, more signals were missed (higher workload) compared to the group of non-diabetics in a medium curve (p<0.03), a wide curve (p<0.02), when driving on a straight road (p<0.02) and in case of a suddenly appearing vehicle (p<0.05). The response times to the secondary task were higher (higher workload) when driving in a sharp curve (p<0.02), a medium curve (p<0.01), a wide curve (p<0.01) or when approaching a STOP sign (p<0.01) in comparison with a non-patient group. The swerving in the lane was less (safer) for Type II diabetics with a normal blood sugar level compared to the control condition in sharp curves (p<0.02) but more (less safe) when approaching a STOP sign (p<0.01). The SD of the steering was lower (safer) for the Type II patients compared to the control condition (p<0.04) in sharp curves. The speed in sharp curves was also lower (safer) for diabetics with euglycaemia (safer) compared to non-diabetics. The percentage of the time that the TLC is less than 1 second in sharp curves is lower (safer) for the Type II diabetics (p<0.01) with the normal blood sugar level.

With a low blood sugar level, Type I (aware) diabetics drove with a lower speed compared to a normal blood sugar level in sharp curves (p<0.02). No difference was found on any of the other variables.

In case of hypoglycaemia, response times for the Type I (unaware) diabetics to the secondary task were higher (more workload) when approaching a crossing pedestrian compared to the normal blood sugar level (p<0.05). With a low blood sugar level, the swerving in the lane is less than with a normal blood sugar level when approaching a STOP sign (p<0.05). The SD of the steering was higher (less safe) in case of a suddenly appearing vehicle (p<0.04). They drove a little slower
with a low blood sugar level (p<0.04) when negotiating a sharp curve. The percentage of time a TLC was lower than 1 seconds when driving on a straight road was lower?? (safer) for a low blood sugar level in diabetic patients (p<0.01).

When we compare the normal blood sugar level and a low blood sugar level in patients of Type II, we find that the percentage of time exceeding the centreline marking in a wide curve is higher (less safe) for the low blood sugar level (p<0.03). No effect was found on any of the other performance levels.

4 Conclusions

In summary, all results have to be taken together in order to have a good understanding of what kind of performance changes in diabetics or when experiencing hypoglycaemia. In order to get such an overview, several performance levels have to be combined. For performance on the secondary task (which is a measure of workload), response times to the task and percentage missed signals are weighted in the same manner. For driving performance, the effects of mean speed, line crossings and SD of lateral position are taken together.

When we try to see whether there is an effect of the mere fact of being a diabetic, we have to compare performance of diabetics with a normal blood sugar level to the performance of non-diabetics (also with a normal blood sugar level). In case we find that there is a difference between those two groups, this difference can be attributed to the mere fact of having diabetes, since there is no difference between their blood sugar level. Table 1 summarizes the effects.
Table 1: Diabetes Effects On Workload And Driving Performance, With 0 Indicating There Is No Difference Between This Group Of Diabetics And Non-diabetics, + Indicating Better Diabetics Performance, And - Indicating Worse Performance Of Diabetics (Type I (a): Type I Diabetics (Aware); Type I (u): Type I Diabetes (Unaware); Type II: Type II Diabetics).

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<th>Motorway</th>
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<td>Normal driving</td>
<td>Critical scenarios</td>
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<td>Type I (u)</td>
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<td>Type II</td>
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From this summarising table, it can be concluded that when diabetics have a normal blood sugar level, some differences are already found with non-diabetics. In general, for Type I (aware) diabetics, the driving task appears to be a little bit more demanding than for non-diabetics, although their driving performance was also somewhat safer. Therefore, it can be concluded that under conditions of normal blood sugar levels, the driving performance of Type I (aware) diabetics is at least as well as that of non-diabetics. For Type I (unaware) diabetics, this is also the case. The experienced workload (i.e. the effort spent) is a little bit higher, but driving performance is also a little better than that of non-diabetics.

When we look at the performance of Type II diabetics under conditions of normal blood sugar level, more workload is experienced during driving. This extra load is accompanied by slightly unsafer driving performance, although driving in city roads in critical scenarios is at least as good as for non-diabetics. Thus, there is some indication that the performance of this type of diabetics is overall slightly worse, since they experience more workload and have worse performance under some conditions.

If we look at the effect of hypoglycaemia in diabetic patients, a summarising table is also required. Table 2 shows the effect of a low blood sugar level in the three different types of diabetics compared to a normal blood sugar level of the same group, taking the difference into account between ride 1 and ride 2 in the non-diabetics group.
Table 2: Hypoglycaemia Effects On Workload And Driving Performance, With 0 Indicating There Is No Difference When Driving Under Low Blood Sugar Level, + Indicating Better Performance And - Indicating Worse Performance.

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<td>Type 2</td>
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When interpreting this table is can be seen that the effect of a low blood sugar level is also present in some conditions. For the Type I (aware) diabetics, there appears to be no effect at all. With a little more effort spent under some conditions, driving behaviour is at least as good, if not better than with a normal blood sugar level. Type I (unaware) patients also spent a little bit more effort, with the same driving performance. For Type II diabetics the effect is at its clearest, with more experienced workload during the task when their blood sugar level is low, and slightly decreased driving performance. For this group, the effect of a low blood sugar level is most outspoken.

4 Discussion

The results from this extensive driving simulator study are clear. For Type I diabetics (aware and unaware), there were no negative effects on driving performance. Under some conditions, slightly more workload is experienced, but this does not result in any negative effects on driving behaviour. There are, however, indications that the Type II diabetics are worse in this respect than non-diabetics. This effect is small under a normal blood sugar level, but it is more evident when the blood sugar level is low. Under these conditions, it is important that Type II diabetics stop their driving as soon as possible.

5 References


THE EFFECT OF TRAFFIC FLOW IMPROVEMENTS ON DRIVER ATTITUDES TOWARDS PAVEMENT MARKINGS AND OTHER TRAFFIC CONTROL DEVICES AND PEDESTRIAN SAFETY

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Background

In the USA, society's dependence on the personal motor vehicle has grown exponentially during the past 50 years. Today, as a result of this almost total dependence, a large majority of motorists outside of the major metropolitan areas have never been pedestrians in the true sense of the word. Of course they walk short distances to and from their vehicles at the home and destination ends of their trips, but very few of them routinely walk across public streets and highways on a daily basis. Instead, their walking is almost exclusively limited to crossing parking lots or sidewalks as close as possible to destinations or inside shopping malls. Children are more and more frequently “taxied” between activities and do not gain valuable experience as pedestrians. Consequently, when they are old enough to drive and are behind the steering wheel of a motor vehicle, their driving behavior either consciously or subconsciously can pose a danger to the safety of pedestrians. In this context, according to the National Highway Traffic Safety Administration 1 almost 5,000 pedestrians were killed and 85,000 injured in traffic crashes in 1999. As such, pedestrian safety is recognized as a serious national concern in the US.

To compound this problem, over the same period, many innovative transportation related planning and engineering changes have been successfully implemented. The intent of these changes has been to make the most efficient use of existing street and highway facilities and developing technology. In addition to tangible improvements such as turn lanes, high-occupancy vehicle lanes, reversible lanes, more sophisticated traffic signal systems, and driver information systems, drivers have been given choices that they never had before. For instance, the red indication on the traffic signal does not necessarily mean that you have to stop and wait until you receive a green signal indication. In this context, if a motorist is in the right hand curb lane believes that a large enough gap exists in the cross-street traffic moving from left to right in the curb lane, then he or she is generally permitted to make a right turn on red (RTOR) after having first come to a complete stop. Prohibitions to the RTOR rule do exist - some are outright bans and some are time-of-day-related.

In some states, it is also possible to make a left turn on a red traffic signal indication, although this is restricted to making a left turn onto a one-way street where the cross traffic moves from right to left. Again, temporal or situational prohibitions similar to that of RTOR exist, but what makes this choice potentially more dangerous to pedestrians and motorists alike is the very fact that this left turn on red (LTOR) practice is permitted is some states but not in others. For example, a motorist from Virginia, a state that permits LTOR and borders North Carolina, may assume that LTOR is also permitted in North Carolina. Clearly, in a non-LTOR state, the absence of signs prohibiting LTOR does not mean that LTOR is permitted.
Other examples of choices given to or taken by the motorist include; traffic signals that transition into a flashing mode during the middle of the night, changing lanes without signaling, and implied (but not widespread posted) speed limits.

Further, during the act of driving, today's motorist is saturated with information of varying value that can affect his or her ability to make quick and correct decisions (at best) or can confuse him or her (at worst), thereby affecting the way the vehicle interacts with other vehicles on the same street or highway, and with pedestrians. Radios have been a standard feature in vehicles for a long time, but now they can be (and frequently are) played louder than ever before (drowning out external noises), and there are tape and disk players, which periodically require attention from the motorist. On-board computers that provide navigational information are now beginning to appear as options. Using cellular phones, smoking, and eating while driving are also well-documented distractions, as is the presence of passengers.

Outside of the vehicle, the motorist has to contend with numerous similarly distracted motorists, street and highway signing of uniform content and design but varying degrees of adequacy, plus pedestrians, bicyclists, parked vehicles, and choices.

Choices by themselves are not bad, but with respect to the act of driving, today's society may have more choices than is "good" for it. Right turn on red was instituted for sound transportation, economic, and environmental reasons (i.e., increase capacity, reduce delays, reduce emissions), and if the maneuver is conducted in accordance with the law and in a safe manner, then all of these goals can be achieved. However, if the maneuver is conducted where it is prohibited or unsafe, then personal safety of the driver and other individuals is jeopardized, regardless of whether or not the other goals are achieved. Motorists who, for example, do not come to a complete stop before making a RTOR may think that they are still making a safe maneuver, but what they have done is interpreted the law to benefit themselves at the risk of others' safety.

Once a few rules have been bent through personal interpretation, it can carry over to other traffic laws that are intended to be absolute, i.e., not subject to interpretation. For example, some motorists no longer come to a complete stop at STOP signs; they treat them more like YIELD signs; others ignore YIELD signs completely. And, what has in recent years become a national epidemic, is that a growing number of motorists do not slow down for yellow traffic signal indications, but speed up and frequently go through intersections when the signal indication is red - "red light running".

This paper is not intended to explain why a particular motorist will or will not drive in an unsafe manner, or subject him/herself to distractions while driving, or to interpret traffic laws to his/her individual advantage, but to suggest that this behavior is a cumulative result of being given choices.

**Literature Review**

Driver handbooks issued by state divisions of motor vehicles (or equivalent agencies) focus on the administrative and legal requirements for obtaining a driver license, basic driving skills and safety issues, and traffic laws, signs and markings. Emphasis is generally directed
toward the new driver or new resident reading the handbook, and the operation of his or her vehicle with respect to other vehicles on the same roadways. Pedestrians are mentioned but, except in a few states’ handbooks, the coverage is not extensive and does not make the driver aware of the driving behavior necessary when interacting with pedestrians.

The North Carolina Driver’s Handbook 2, for example, contains a detailed discussion on the driver’s responsibilities and requirements to yield right of way to pedestrians as well as the responsibilities of pedestrians. It specifically mentions the requirement for the driver to stop at the appropriately marked stop line in advance of a crosswalk. It also advises the driver that unless there is a sign indicating NO TURN ON RED, he or she can turn right on red after stopping and making sure that the turn can be made safely. Notably, it does not directly advise the driver how to combine the stop at the stop line with the maneuver to position the vehicle for making a permitted right turn on red (RTOR).

In Chapter 4 of the Massachusetts Driver’s Manual 3, further clarification on driver behavior at an intersection is provided by the statement that “you may not enter an intersection or drive across a crosswalk unless there is room for you to drive through to the other side safely. Obstructing the paths of other vehicles or pedestrians in an intersection or crosswalk causes traffic jams and violates traffic law.” Interestingly, the passage does not mention that the safety of pedestrians might also be jeopardized; however, pedestrian safety is addressed elsewhere in the manual.

Publications by pedestrian and safety advocacy groups were also examined. One such group, the Pedestrian and Bicycle Information Center (PBIC), was established at the University of North Carolina Highway Safety Research Center with funding from the USDOT “to connect communities with the information and resources they need to create safe places for walking and bicycling”. In its information series on Design and Engineering/Signals and Signs 4, the PBIC recommends that signs should prohibit RTOR wherever and whenever there are high pedestrian volumes. It further recommends that vehicle stop lines should be moved back (“recessed”) by 15 to 30 feet from pedestrian crosswalks at both signalized and non-signalized locations for an improved factor of safety and for improved visibility of pedestrians.

Another safety advocacy group, the Advocates for Highway and Auto Safety, published the results of its third annual survey of national attitudes related to highway and auto safety in 1999 5. Conducted by the Peter Harris Research Group, under contract to Louis Harris, researchers queried participants about the level of attention that should be directed toward making dangerous intersections safer for pedestrians. In response to the option of a) much more attention, b) somewhat more attention, or c) leave as it is,” results indicated that “much more attention” was chosen by 57% of all respondents, with women feeling the need more than men (62% vs. 52%) and elderly persons more than younger persons (60% vs. 52%).

The Insurance Institute for Highway Safety (IIHS) conducted a study at 15 intersections in Arlington, Virginia to evaluate two methods for restricting RTOR at intersections where pedestrians are present 6. The two methods were: signs prohibiting RTOR during specified hours; and signs prohibiting RTOR when pedestrians are present. The study found that signs prohibiting RTOR during specified hours were very effective at increasing the proportion of drivers stopping at stop lines (from 21% to 40%). Also, the proportion of RTOR drivers who did not stop, decreased from 32% to 13%, and the proportion of pedestrians who were forced
to yield to turning vehicles decreased from 17% to 7%. Signs giving drivers discretion to turn right on red based on the presence of pedestrians were not effective.

The Environmental Working Group and the Surface Transportation Policy Project jointly published a report in 1997 titled “Mean Streets” 7. The group noted that more than half of all pedestrian deaths by motor vehicles occur on neighborhood streets, and that it was not a question of pedestrians walking in the wrong places. Instead, the local streets were becoming speedways, designed to accommodate more cars passing through, not the people who walk in their communities.

Several cities and states have taken steps to address conflicts between motor vehicles and pedestrians. In Arizona, the Department of Transportation’s crosswalk policy 8 acknowledges the different perspectives that pedestrians and drivers have about marked crosswalks, and recommends that they not be installed unless anticipated benefits clearly outweigh their associated risks. In essence, the message is that marked crosswalks by themselves should not be considered to be pedestrian safety devices. On a marked crosswalk, a pedestrian may have a false sense of security and place him/herself in a hazardous position with respect to vehicular traffic, since a driver’s view of a crosswalk is greatly reduced at the safe stopping distance due to the viewing angle and the distance. Street alignment, pavement irregularities, weather, dirty windshields, glare, and adverse lighting conditions also affect the driver’s view of the crosswalk.

The Atlanta-based Pedestrians Educating Drivers on Safety, Inc. (PEDS) suggests behavioral changes for drivers and residents that should contribute toward making Atlanta more walkable 9. PEDS disseminates information to increase the awareness of applicable state laws concerning right of way, including the requirement that drivers must stop behind crosswalks, not on top of them. In the metropolitan Atlanta area, the National Center for Injury Prevention and Control (NCIPC) conducted an investigation of pedestrian fatalities in four counties and concluded that the annual pedestrian fatality rate was not only consistently higher than the national rate, but also steadily rising 10. The NCIPC suggested safety tips for pedestrians and drivers. One pedestrian warning was “Do not assume that a green light, a WALK signal, or a crosswalk means that the street is safe to cross. As some drivers may disregard traffic rules, you must be aware of vehicles even when you have the right of way.”

Drivers, on the other hand, are urged to: (1) yield to pedestrians and not to attempt to pass in front of or around pedestrians while they are in a crosswalk; (2) stop well short of the crosswalk when stopping at an intersection, so as not to block pedestrians crossing signals; (3) look to the right, as well as to the left, when making a right turn on red, so as not to miss a crossing pedestrian; and (4) be attentive to pedestrians, even when operating a radio, cellular telephone, or lighting a cigarette, since any one of these activities can divert attention long enough to hit a pedestrian.

In metropolitan Nashville, Tennessee (pop. 570,000), the Metropolitan Planning Commission’s Traffic and Pedestrian Safety Task Force published a report in 1998 that included suggestions for decreasing congestion and promoting traffic and pedestrian safety. 11 The report noted that during the three year period from 1995 to 1997, the Metropolitan Police Department issued over 125,000 citations for speeding, over 24,000 for careless and reckless driving, over 15,000 citations for failure to stop or yield at intersections, and over 6,000 citations for turning when prohibited. The task force concluded that people are discouraged from walking because vehicular traffic makes them feel unsafe, the lack of education about traffic laws contributes to unsafe driving, and there is an apparent lack of compliance with...
existing traffic laws. Included in a list of pedestrian improvements was a recommendation to “prohibit RTOR in selected downtown-area intersections.”

The extent to which pedestrians comprehend traffic control devices was the subject of a study conducted by two University of Tennessee researchers\textsuperscript{12}. Four types of information were collected from respondents: demographic characteristics, problem assessment, knowledge of pedestrian laws, and knowledge of pedestrian traffic control devices. Findings indicated that a significant number of respondents misunderstood traffic laws, signals or signs related to pedestrians, leading the authors to conclude that if traffic control devices are misunderstood to this extent, then traffic engineers are not properly serving the community.

Analogously, driver behavior is the subject of two Canadian reports. In the first report, titled “The Roles of Legislation, Education, and Reinforcement in Changing Road User Behavior,”\textsuperscript{13} the author suggests that several factors have played a role in promoting the current behavior of road users. Further, the author asserts that it is difficult to compare the effectiveness of road safety programs because they have rarely been designed or evaluated according to behavior change. Four methods are proposed for changing behavior: Legislation, Enforcement, Reinforcement and Education. Legislation sets socially acceptable standards and imposes sanctions on violators, but a new law (e.g., seat belts) by itself has limited influence, since the initial effect due to the publicity it gets declines fairly rapidly. Therefore, legislation needs support from the other three methods. Enforcement upholds society’s expectations and standards, however, road users may view sanctions (e.g. fines) as: (1) a cost of doing business; (2) a moral issue; (3) an inefficient and discriminatory systems; or (4) a revenue generator. Reinforcement differs from enforcement in that it focuses on encouraging desirable behaviors rather than discouraging undesirable behaviors. Education helps people develop knowledge, skills and changes in attitude, and feeds the development of internal and informal social controls.

In the second report titled “Risk Mentality; Why Drivers Take The Risk They Do?”,\textsuperscript{14} the author suggests that passive safety strategies (seat belts, air bags, automatic braking systems) are dominant partly because of the poor understanding of driver behavior and the weak behavior change methods used in the past. It is easier and more acceptable to exert pressure on the relatively few automobile manufacturers to produce safer vehicles than to exert pressure on individual drivers to drive more safely. The author concludes that drivers take risks either because they don’t realize they are taking them, or because they are willing to accept them. Furthermore, the vast majority of deaths and injuries on the roads are caused by the actions of “normal” drivers, as opposed to those who are identified as deviant, abnormal or particularly “bad” drivers. In general, normal drivers are motivated to behave in ways they think are useful to their best interests.

Finally, in a reflection on values in our society, US Congressman Dick Armey notes\textsuperscript{15} that although we are more prosperous than ever in material terms, we have become more tolerant of incivility and less concerned about unpunished acts of injustice. This clearly affects everything we do, including driving.

**North Carolina Survey**

To learn more about the traffic-related actions, awareness, and observations of drivers in North Carolina, a survey was developed and administered to a sample of 100 licensed drivers
who are residents of North Carolina. Of the 100 drivers in the sample, exactly one-half were male and one-half were female. One-fifth were 25 years of age or younger; 10 percent had been driving 5 years or less; 70 percent had been driving more than 10 years; and 75 percent learned basic driving skills in high school. For purposes of reporting findings, drivers were split into two age groups: Younger (up to and including 25 years of age) and Older (over 25 years of age).

1. Respondents’ Actions

- 23 percent of the respondents stated that, although they slow down, they do not come to a complete stop at a STOP sign. Younger drivers proportionately exhibited this behavior more than older drivers (45% vs. 18%)

- 17 percent of the respondents stated that, when approaching a traffic signal that has just changed from GREEN to YELLOW, they speed up. In addition, 22 percent stated that they wait to see what the vehicle in front of them is going to do (stop or speed up) before making a decision. Younger drivers speed up more often than older drivers (26% vs. 15%), and wait to see what the vehicle in front is going to do (27% vs. 21%)

- 99 percent of the respondents stated that they slow down and stop if necessary at a YIELD sign

- 99 percent of the respondents stated that, when approaching a pedestrian on a marked crosswalk, they slow down and stop in order to yield right of way to the pedestrian

- 71 percent of the respondents stated that, after stopping at a STOP LINE, they wait for the GREEN signal before moving again. There was no significant difference for sex or age.
2. Respondents’ Awareness

- 95 percent of the respondents responded in a manner that confirmed that they understood the rules for RTOR (which is permitted in North Carolina). Males and females were equally aware of the RTOR rules, as were younger and older drivers.

- Only 75 percent of the respondents knew that a left turn on red (LTOR) is not permitted in North Carolina. The level of understanding was greater for males than for females (82% vs. 68%) and for older drivers as opposed to younger drivers (79% vs. 60%).

- 92 percent of the respondents stated that they knew they were supposed to stop their vehicles at the STOP LINE before a crosswalk. There was no significant difference by sex and age.

- 21 percent of the respondents stated that they had never heard of the STOP LINE before taking the survey. More females had not heard of the STOP LINE than males (30% vs. 12%) and more younger drivers than older drivers (35% vs. 17%).

- 41 percent of the respondents stated that STOP LINES were not clearly marked. Females exceeded males (46% vs. 36%) and younger drivers exceeded older drivers (55% vs. 37%).

- 46 percent of the respondents stated that it was not easy to see where they were stopped relative to the STOP LINE. Females exceeded males (56% vs. 36%) and younger drivers exceeded older drivers (55% vs. 44%).

3. Respondents’ Observations

- 14 percent of the respondents stated that more than occasionally they have stopped their vehicle in a crosswalk and pedestrians have had to walk around their vehicle. There was no significant difference between the sexes, but younger drivers admitted to finding themselves in this situation more often than older drivers (25% vs. 11%).

- 68 percent of the respondents stated that, as pedestrians, they more than occasionally find it necessary to walk around a vehicle blocking a crosswalk. There was no significant difference between the sexes, but younger pedestrians stated they found themselves in this situation more often than older pedestrians (90% vs. 62%).

- 89 percent stated that more than occasionally they observed vehicles not stopping at STOP signs. There was no significant difference between the sexes, but older respondents observed it more than younger respondents (90% vs. 85%).

- 80 percent stated that more than occasionally they observed vehicles not slowing down at YIELD signs. Females observed this more than males (84% vs. 76%).
and older respondents observed it slightly more than younger respondents (81% vs. 75%).

- 80 percent stated that more than occasionally they observed vehicles running RED traffic signals. Females observed this more than males (84% vs. 76%) and younger respondents observed it more than older respondents (90% vs. 77%).

**Observations**

Based upon the results of the survey of North Carolina licensed drivers, the following observations, which may have nationwide driver training and roadway maintenance implications, are made:

- A significant proportion of respondents stated that they are unaware that left turns on red are not permitted in North Carolina.
- A significant proportion of respondents stated that they interpret STOP signs as YIELD signs.
- A significant proportion of respondents stated that they believe that STOP LINES are not clearly marked.
- A significant proportion of respondents stated that they are frequently forced to walk around vehicles stopped in sidewalks.
- A significant proportion of the respondents stated that they frequently observe vehicles not slowing down at YIELD signs and not stopping at STOP signs.
- Although differences in responses exist between male and female respondents, the most significant differences are found between younger and older drivers, with younger drivers always exhibiting a less favorable behavior.

**Conclusions**

- The behavior of a significant proportion of drivers is dangerous not only to themselves, but also to other road users, and pedestrians.
- From a safety standpoint, significant proportions of drivers either ignore traffic control devices or interpret the meaning to suit their own needs.
- The attempt to achieve transportation, economic and environmental goals through traffic capacity improvements can, but does not have to, compete with attempts to improve traffic and pedestrian safety.
Bibliography


